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Nakayasu

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(54) PRINTING APPARATUS AND TONER DENSITY MEASURING METHOD

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(73) Assignee: **Fujitsu Limited**, Kawasaki (JP)

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Jul. 3, 2000 (JP) 2000-200523

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(52) **U.S. Cl.** **399/49**; 250/339.11; 250/341.8

(58) **Field of Search** 399/49, 41, 299; 347/131; 358/504, 406, 296, 298; 250/341.8, 339.11; 356/445

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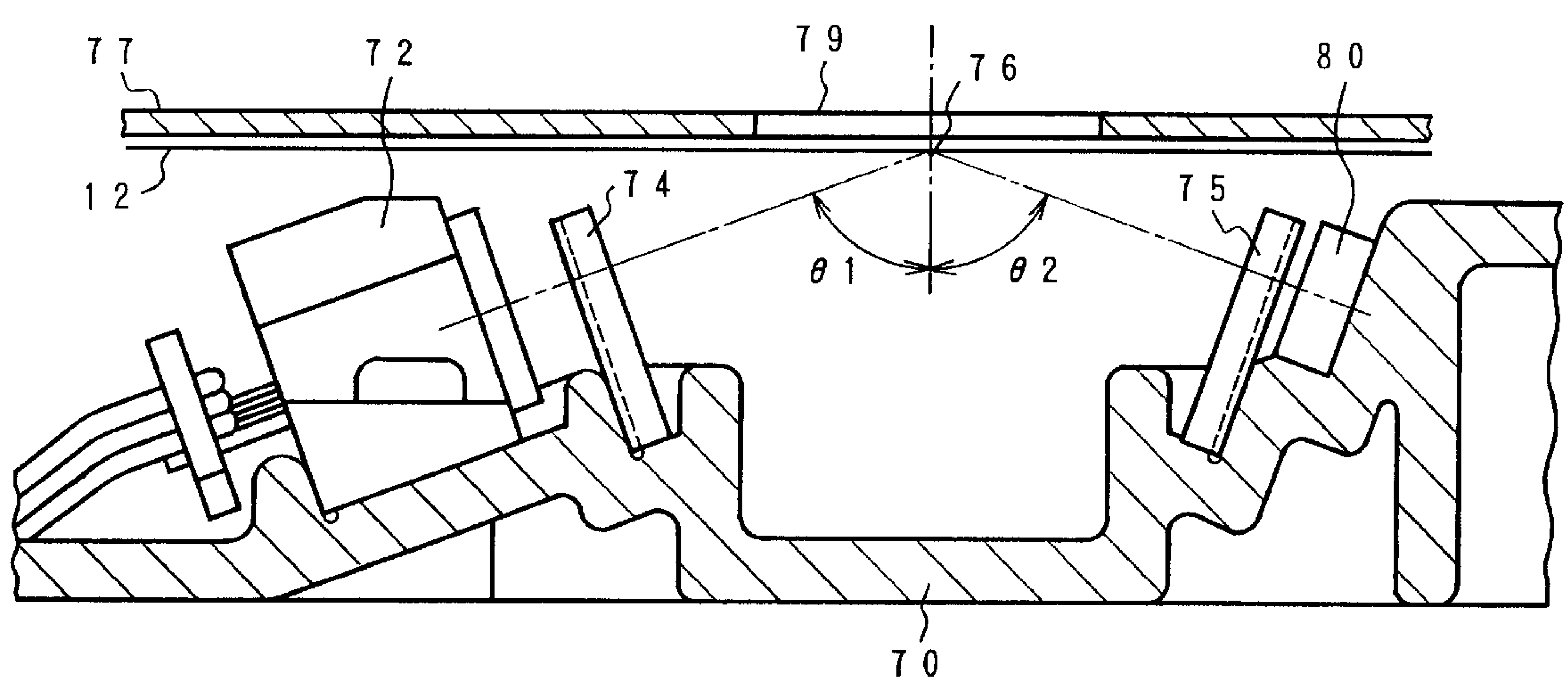
(57) **ABSTRACT**

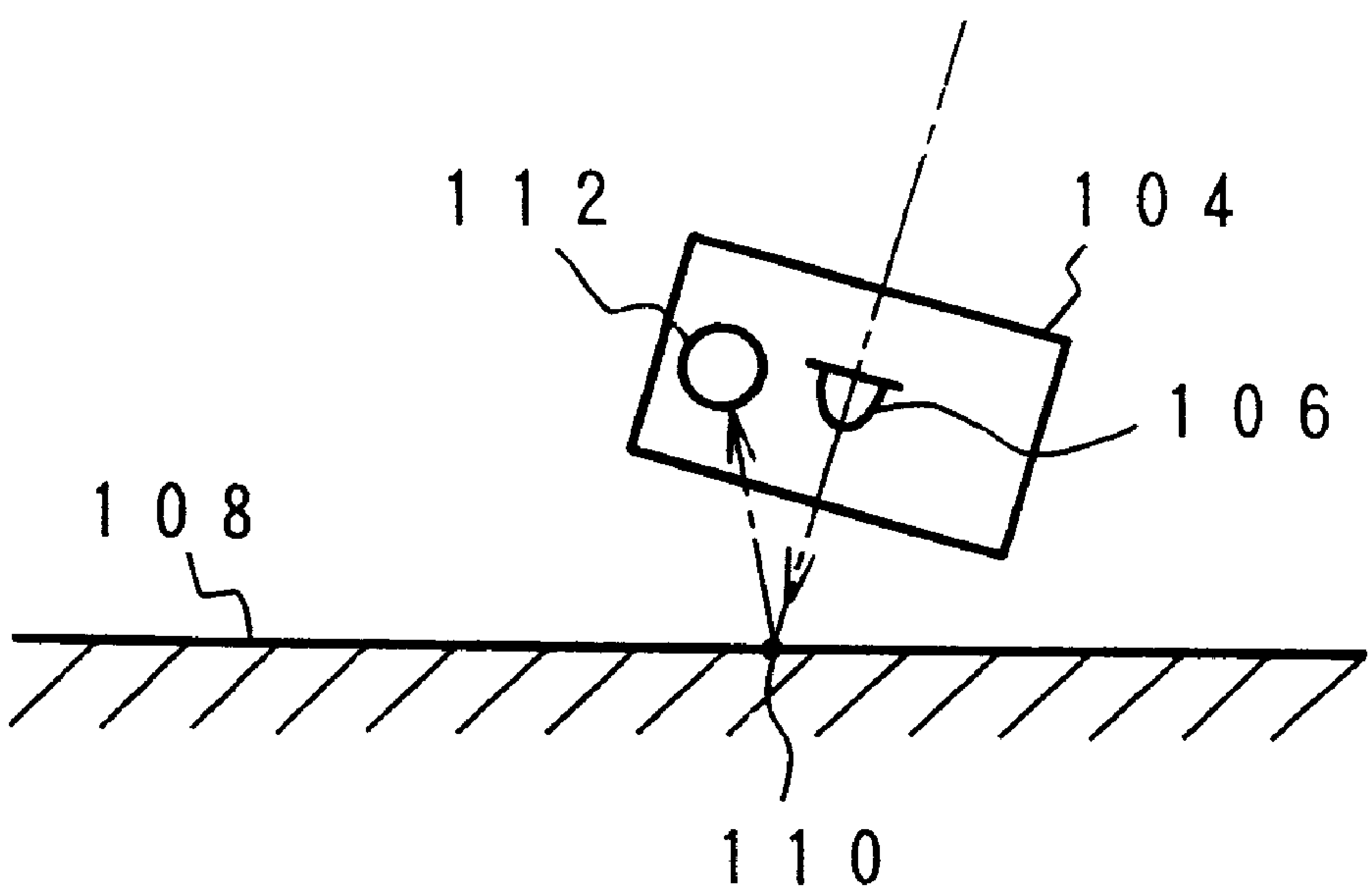
A toner mark transfer unit transfers a halftone pattern such as a transverse line pattern or a slanted line pattern on a belt by using a plurality of electrostatic recording units. A toner density measurement unit figures out density control parameters such as emission time and emission current on the basis of the ratio of a reflected light (inter-line space width) from the toner free portion to a light (line width) attenuated due to a diffuse light from the toner bearing portion in a read signal of a halftone pattern from a sensor unit.

14 Claims, 17 Drawing Sheets

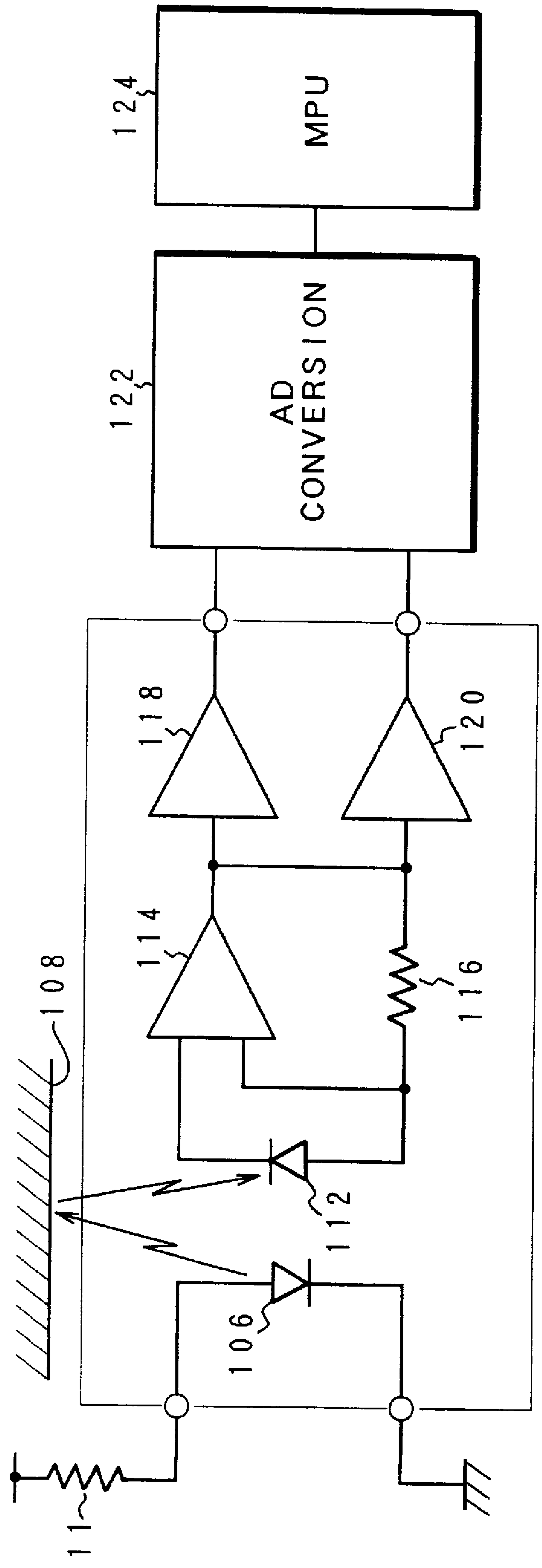


PRIOR ART

FIG. 1



PRIOR ART
FIG. 2



PRIOR ART

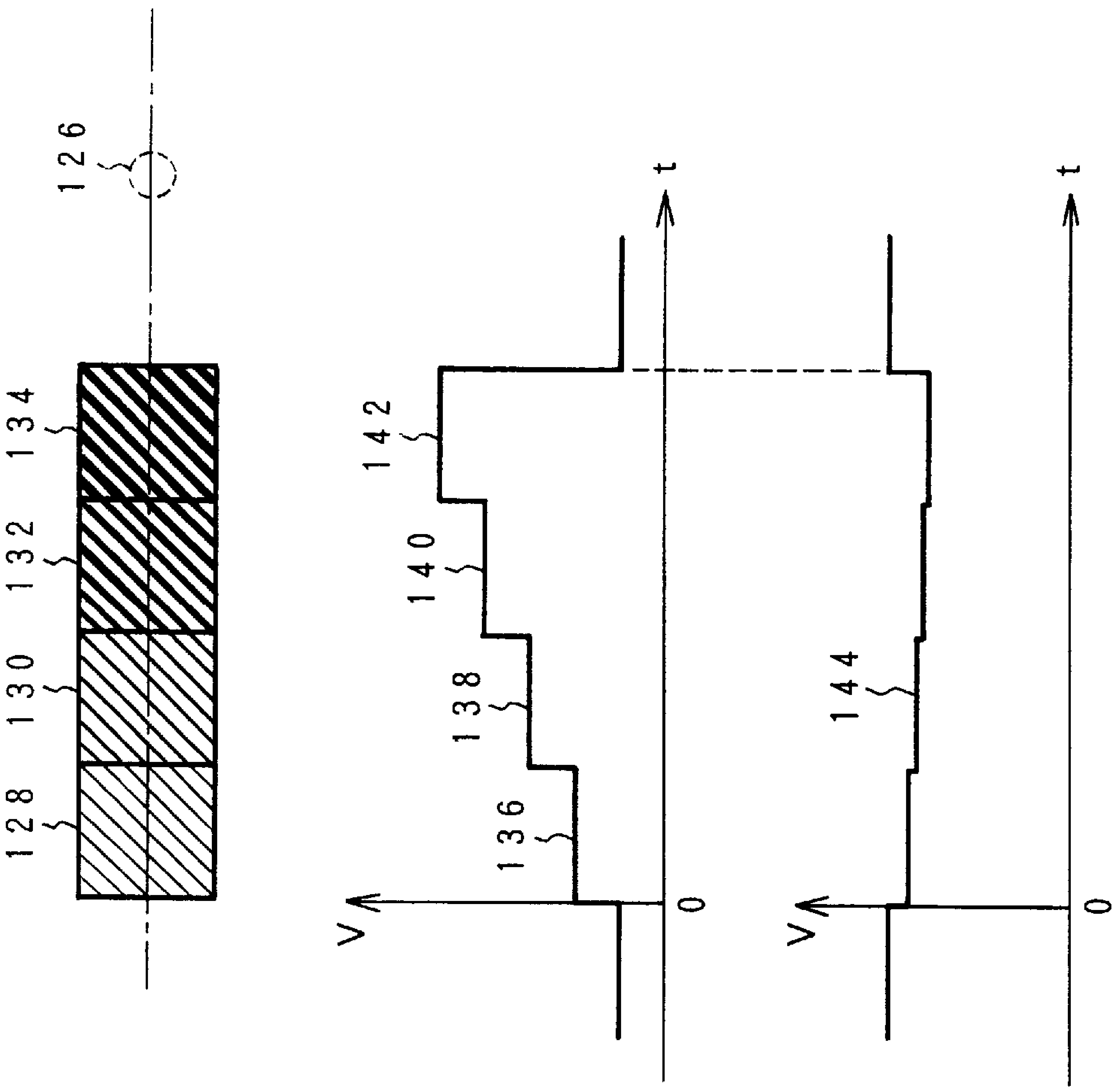


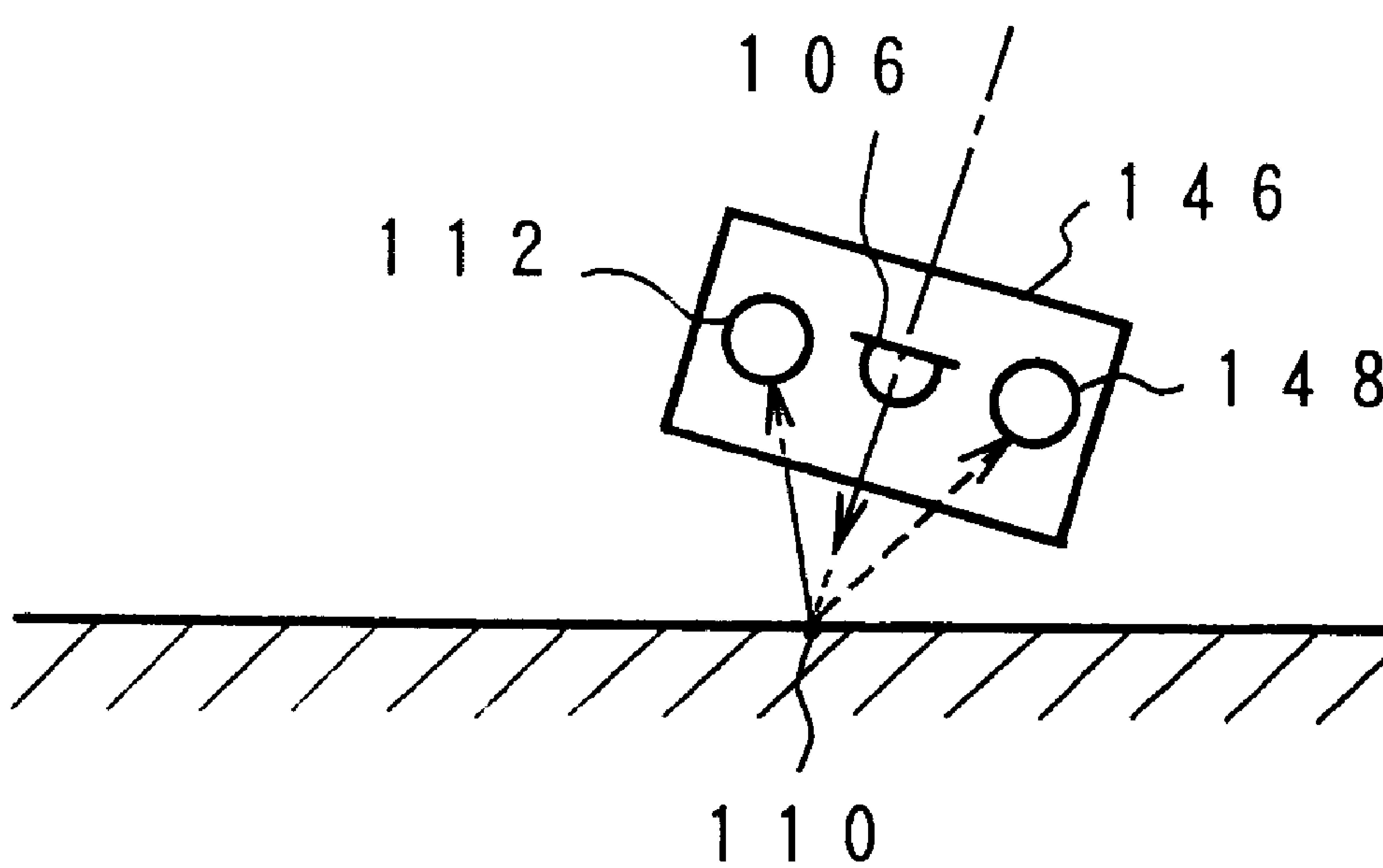
FIG. 3A TONER MARK

FIG. 3B YMC COLOR TONER OUTPUT SIGNAL

FIG. 3C K TONER OUTPUT SIGNAL

PRIOR ART

FIG. 4



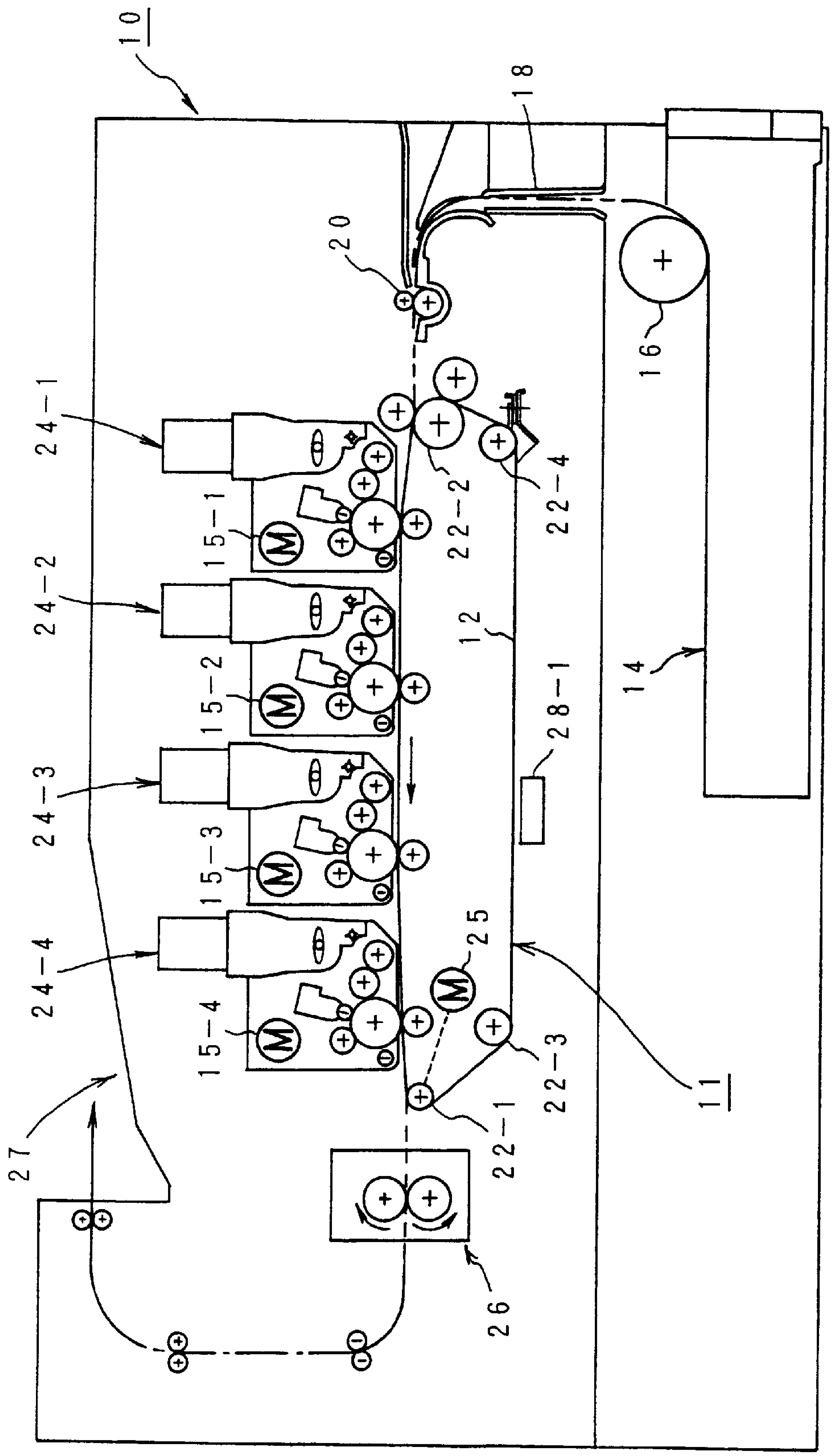

10
18
20
16
24-1
24-2
24-3
24-4
15-1
15-2
15-3
15-4
22-1
22-2
22-3
22-4
12
14
11
25
26
27
28-1

FIG. 5

F I G. 6A

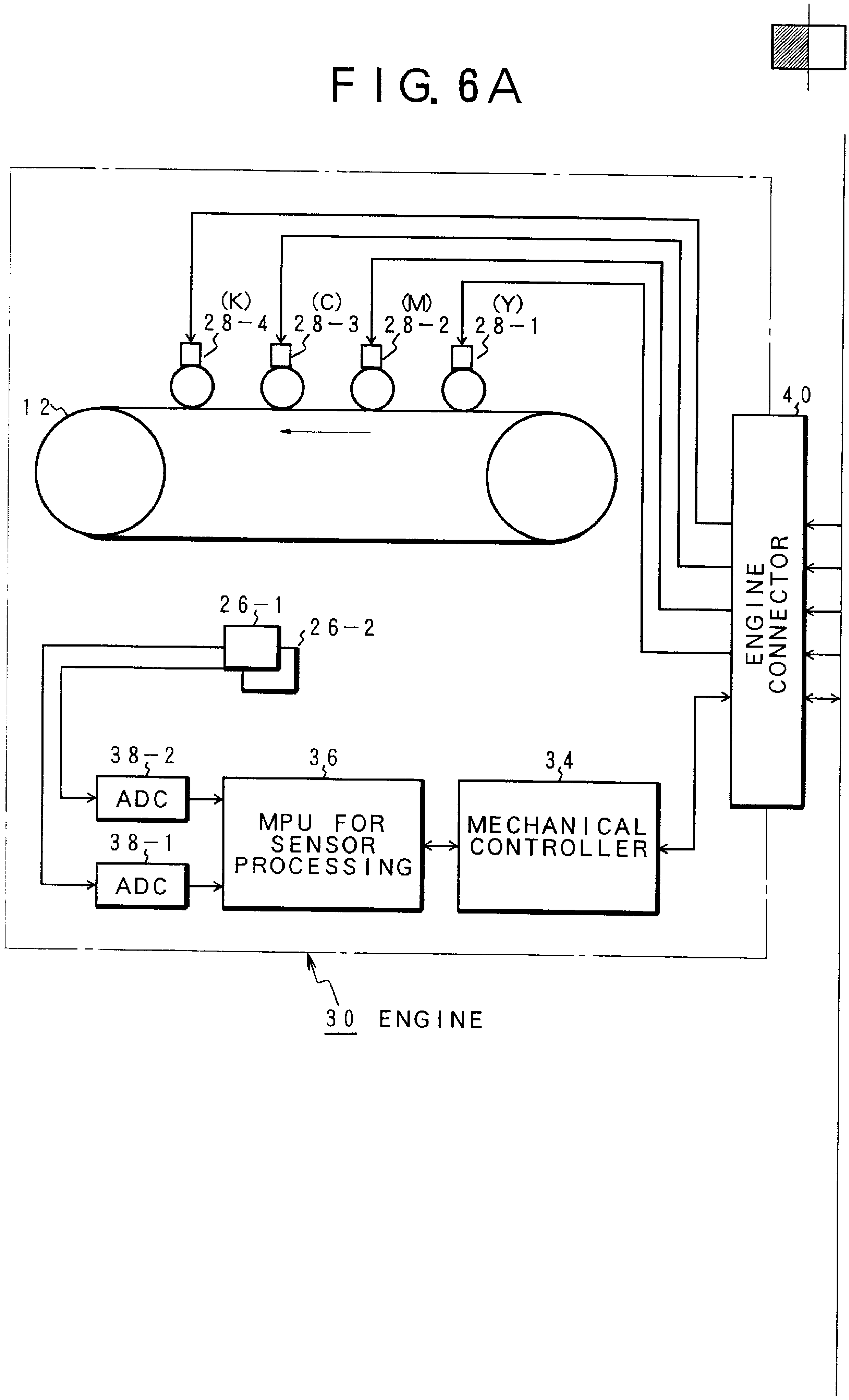
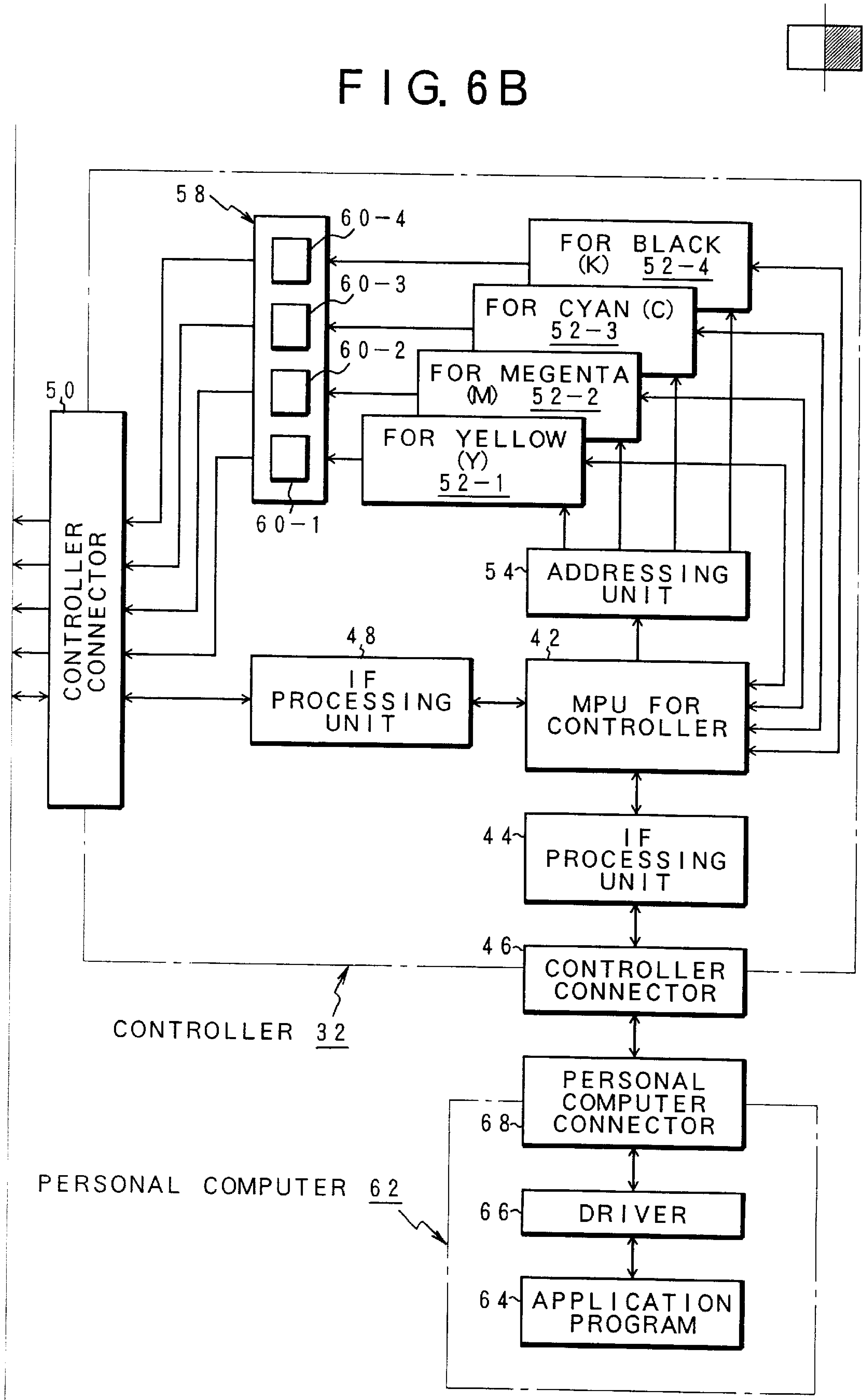

(K)
28-4
(C)
28-3
(M)
28-2
(Y)
28-1
12
40
ENGINE CONNECTOR
26-1
26-2
38-2
ADC
36
MPU FOR SENSOR PROCESSING
34
MECHANICAL CONTROLLER
38-1
ADC
30 ENGINE

FIG. 6B



58
60-4
60-3
60-2
60-1
FOR BLACK (K) 52-4
FOR CYAN (C) 52-3
FOR MEGENTA (M) 52-2
FOR YELLOW (Y) 52-1
50
CONTROLLER CONNECTOR
54
ADDRESSING UNIT
48
IF PROCESSING UNIT
42
MPU FOR CONTROLLER
44
IF PROCESSING UNIT
46
CONTROLLER CONNECTOR
CONTROLLER 32
PERSONAL COMPUTER CONNECTOR
68
PERSONAL COMPUTER 62
66
DRIVER
64
APPLICATION PROGRAM

FIG. 7

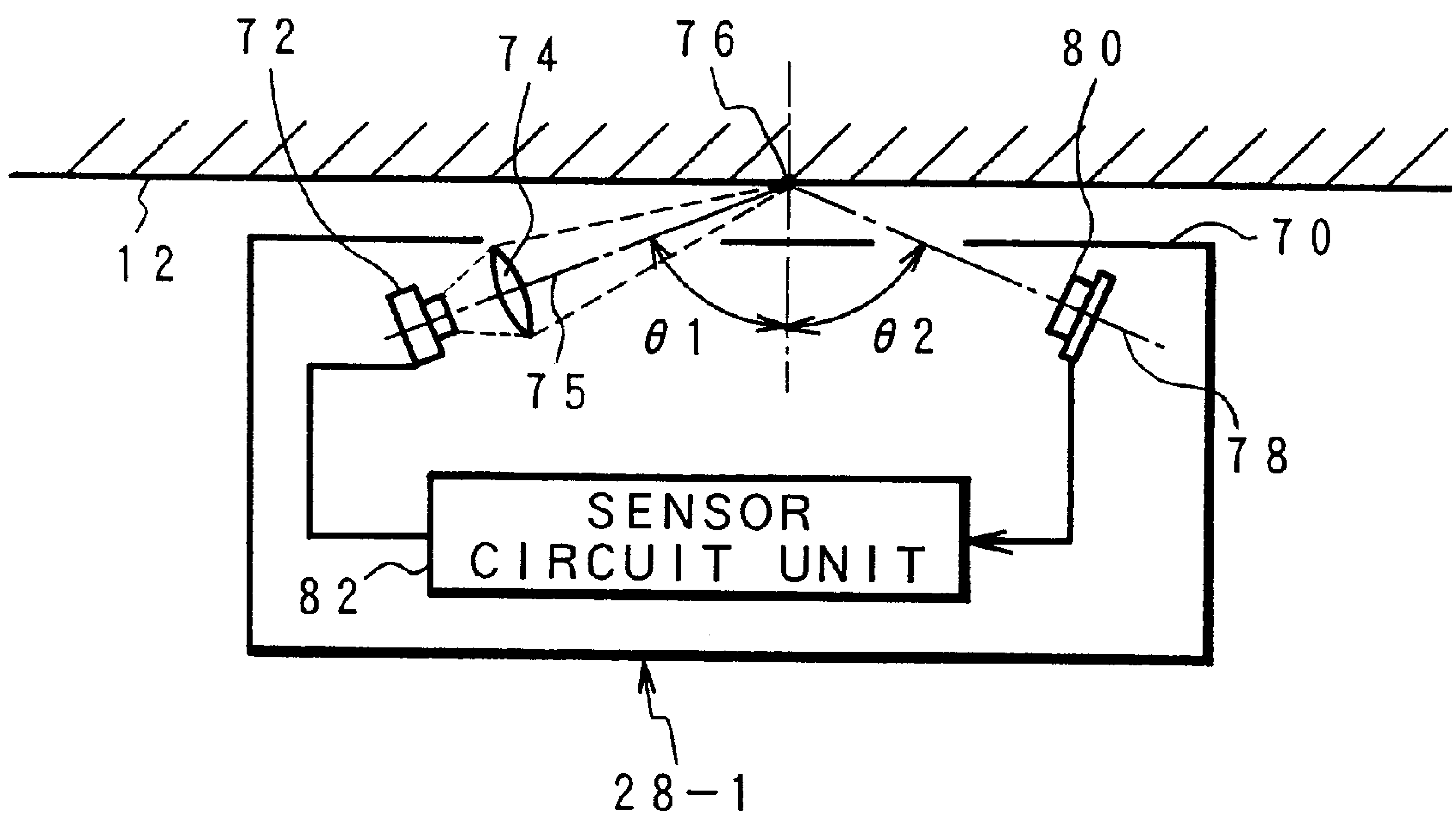
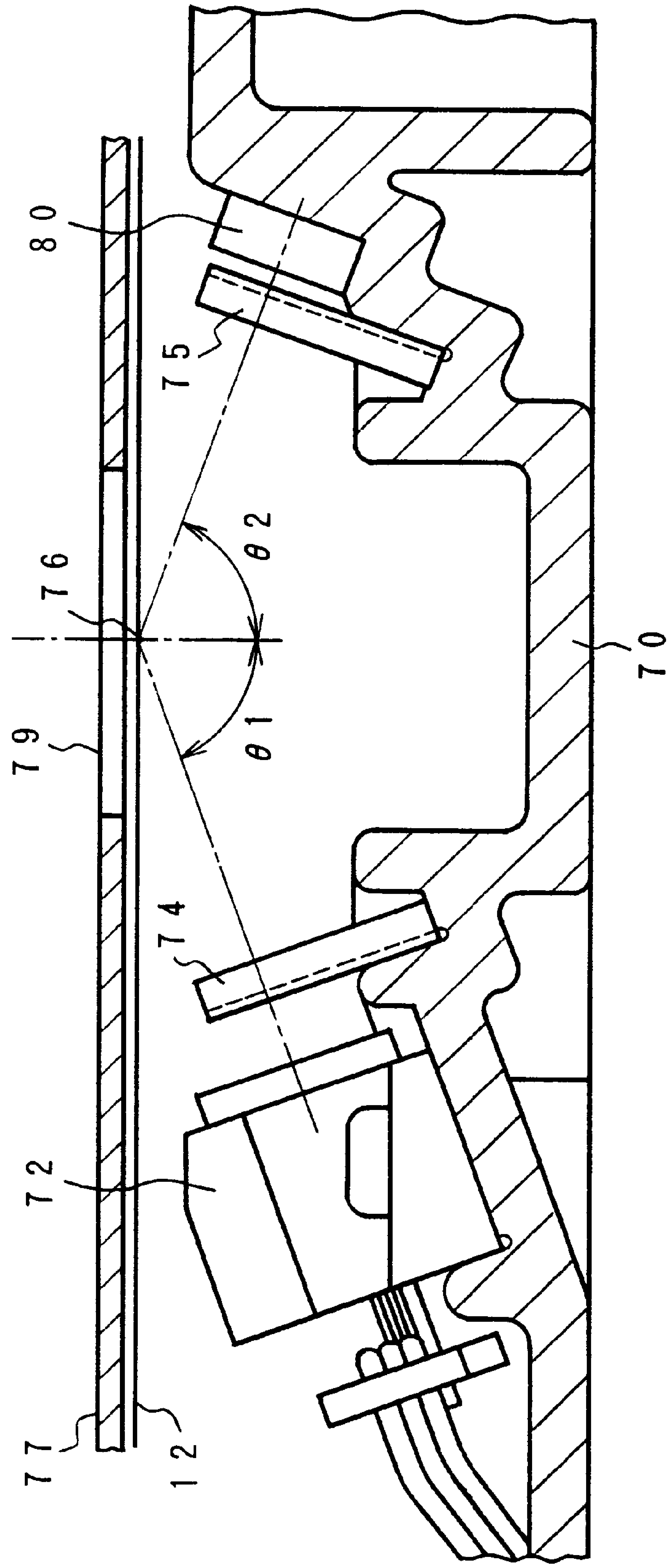


FIG. 8



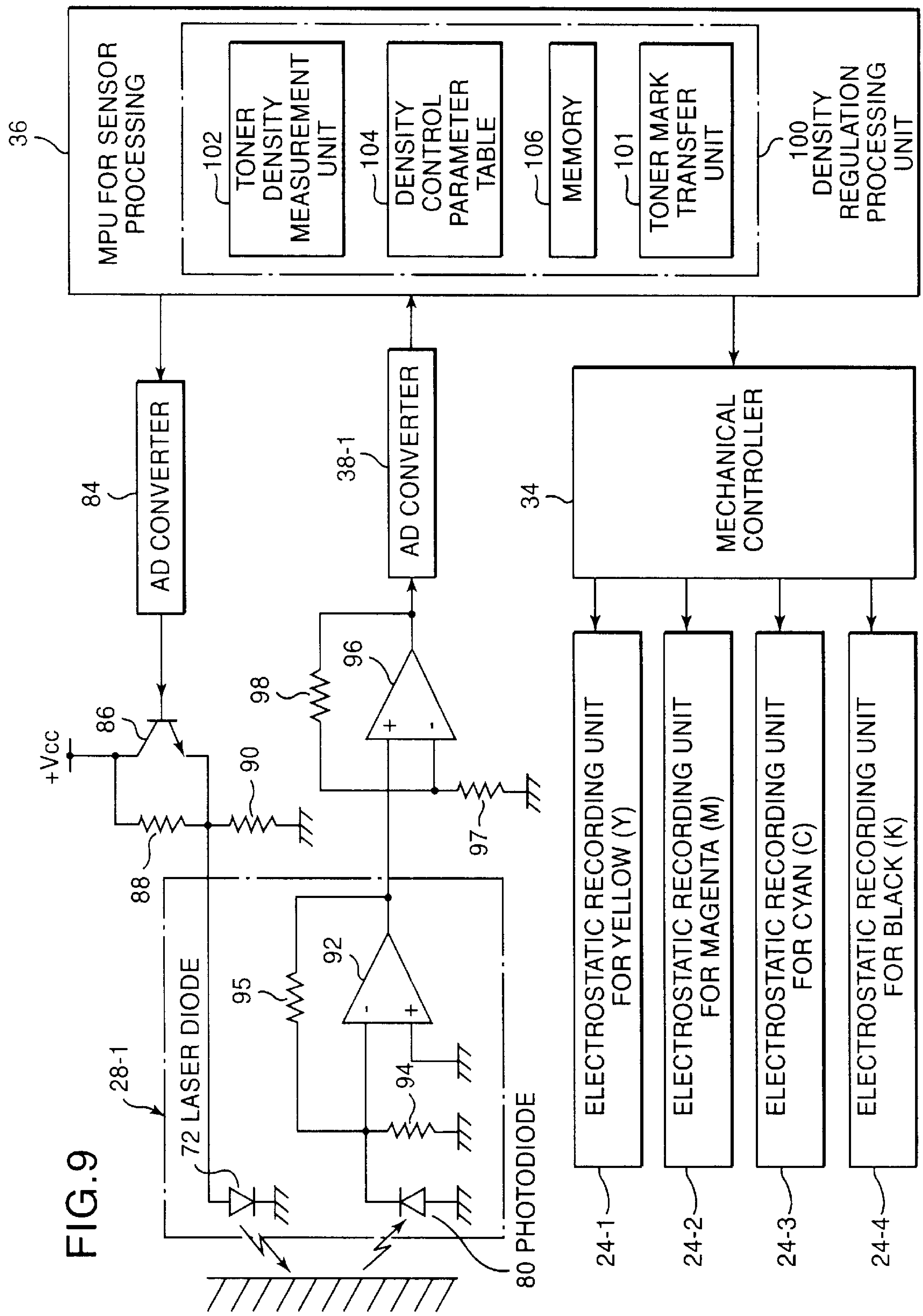

36
MPU FOR SENSOR PROCESSING
102
TONER DENSITY MEASUREMENT UNIT
104
DENSITY CONTROL PARAMETER TABLE
106
MEMORY
101
TONER MARK TRANSFER UNIT
100
DENSITY REGULATION PROCESSING UNIT
84
AD CONVERTER
38-1
AD CONVERTER
34
MECHANICAL CONTROLLER
+Vcc
86
90
88
98
96
97
95
92
94
28-1
72 LASER DIODE
80 PHOTODIODE
ELECTROSTATIC RECORDING UNIT FOR YELLOW (Y)
ELECTROSTATIC RECORDING UNIT FOR MAGENTA (M)
ELECTROSTATIC RECORDING UNIT FOR CYAN (C)
ELECTROSTATIC RECORDING UNIT FOR BLACK (K)
24-1
24-2
24-3
24-4

FIG.9

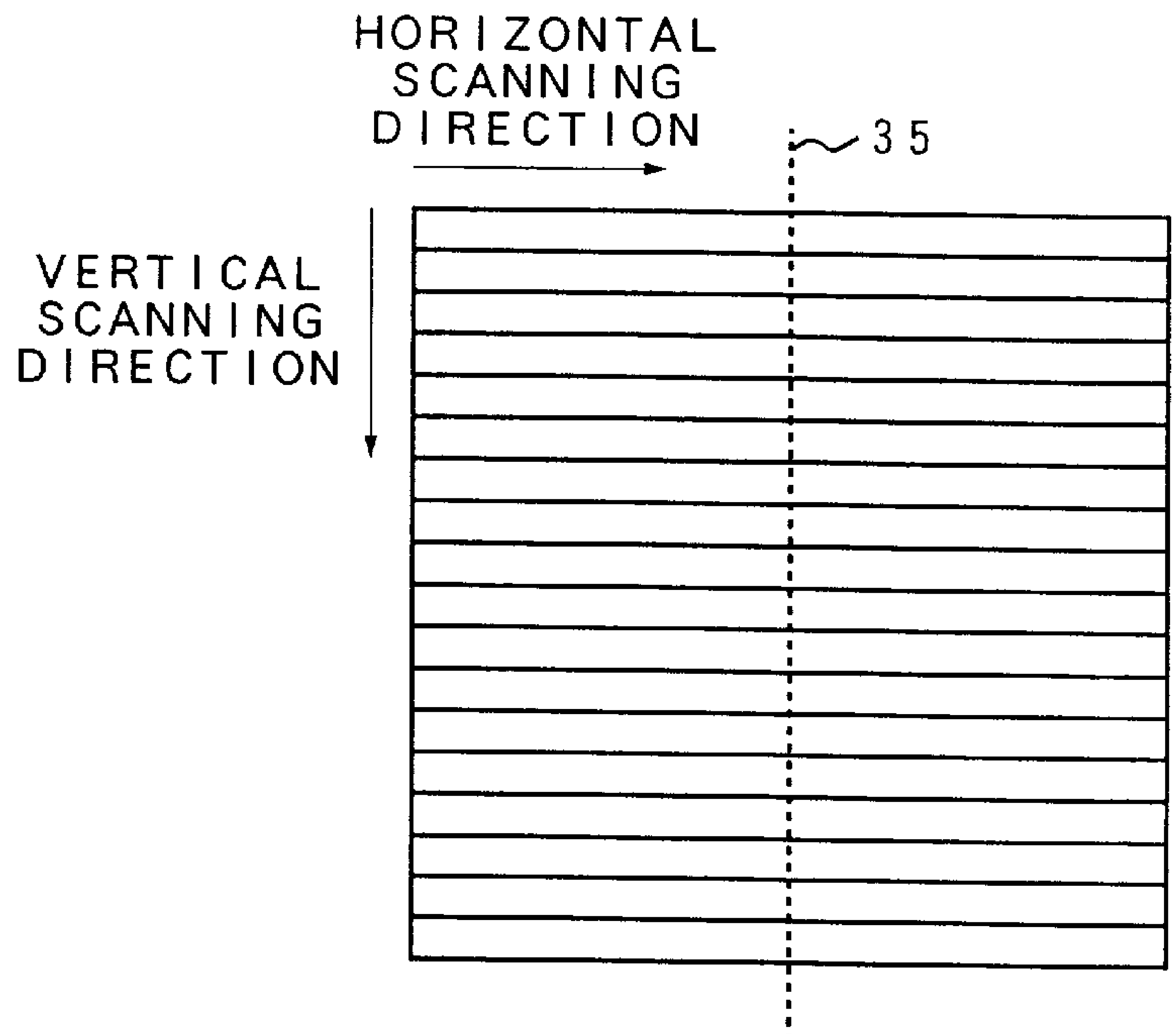


FIG. 10A

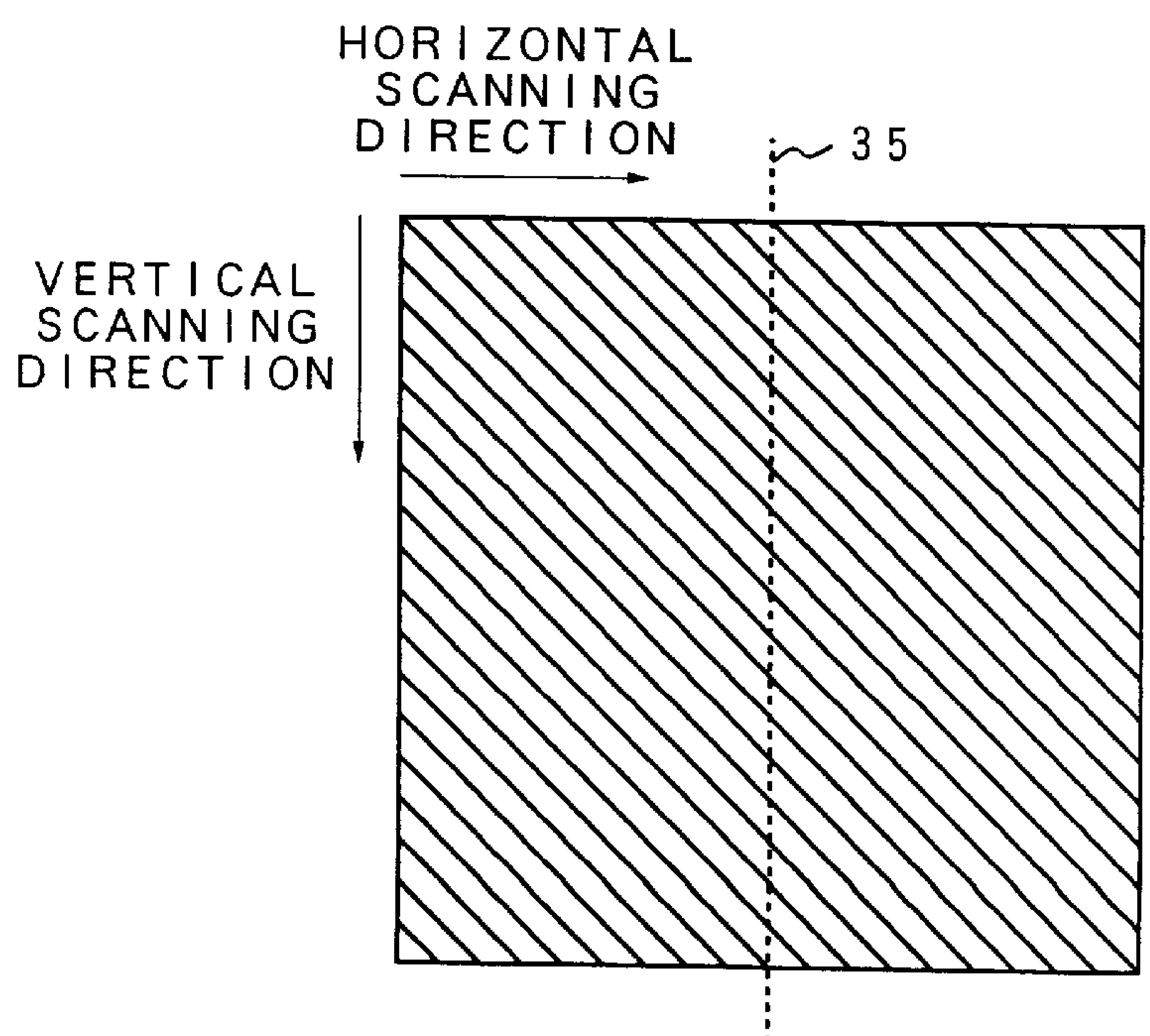


FIG. 10B

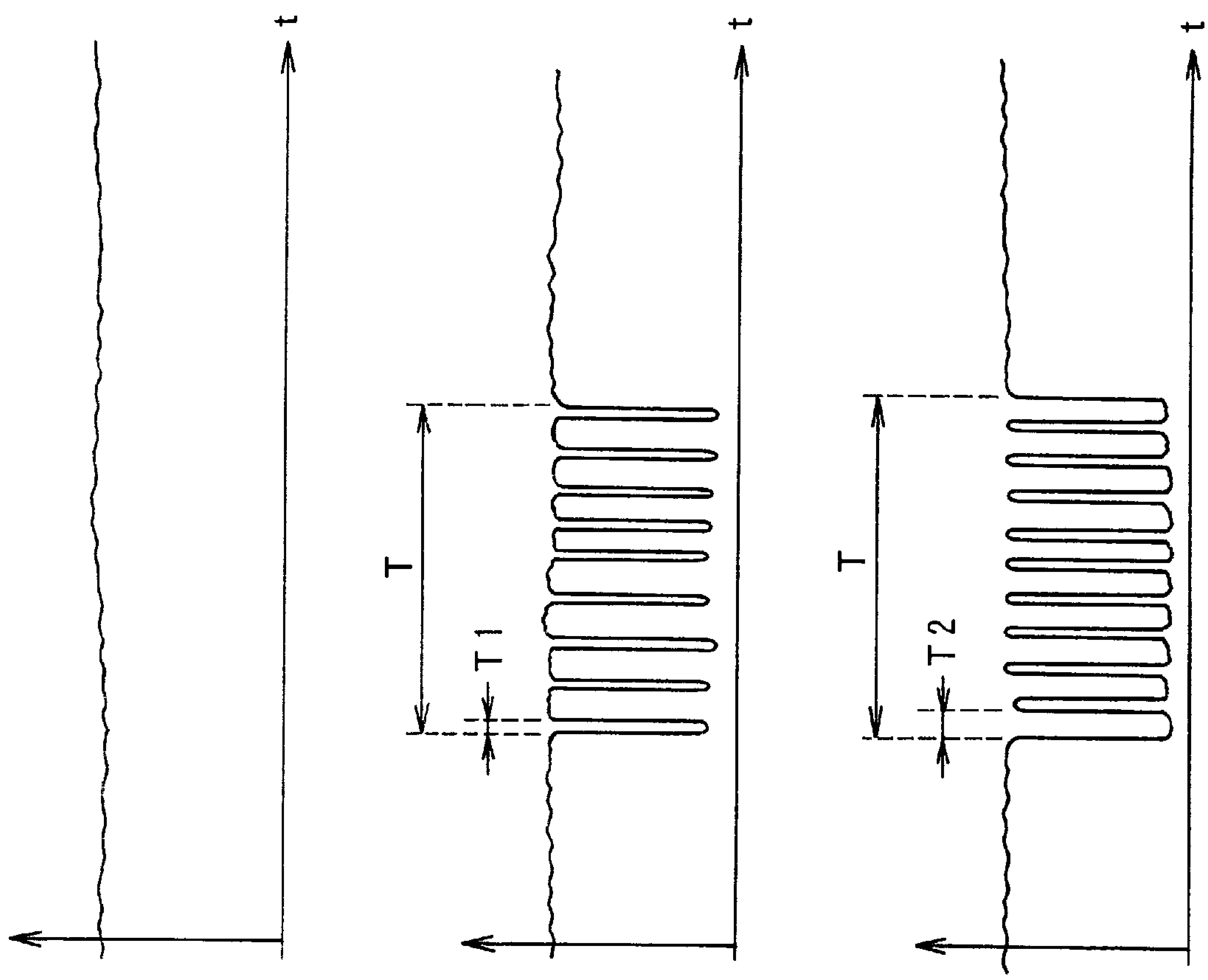


FIG. 11A
NO TONER

FIG. 11B
SMALL QUANTITY OF TONER

FIG. 11C
LARGE QUANTITY OF TONER

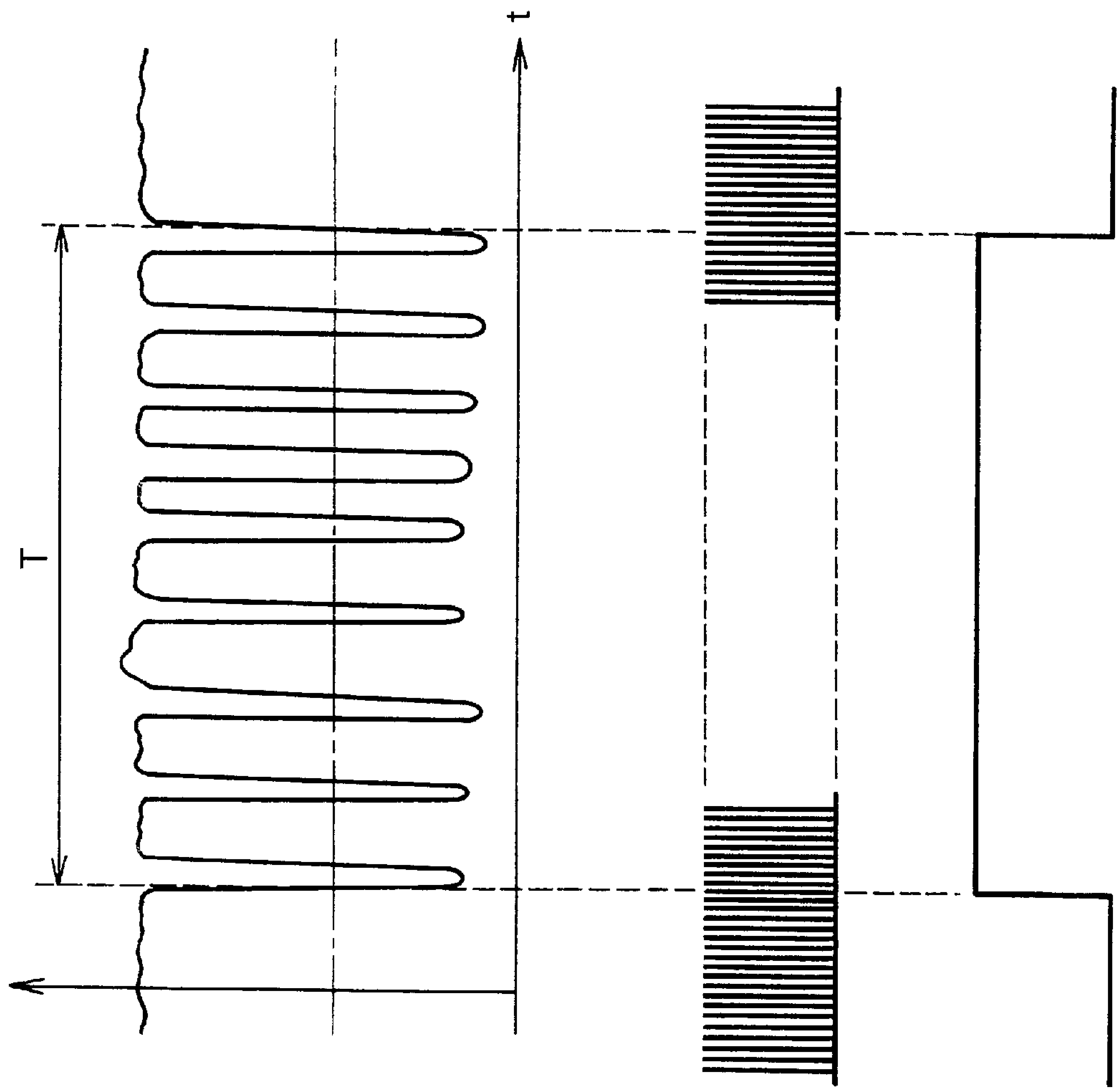


FIG. 12A
PD OUTPUT SIGNAL

FIG. 12B
SAMPLING PULSE

FIG. 12C
SAMPLING GATE

FIG. 13

WHITE-TO-BLACK RATIO	EMISSION TIME
LESS THAN 30%	ERROR
NOT LESS THAN 30% AND LESS THAN 40%	10 μs
NOT LESS THAN 40% AND LESS THAN 50%	12 μs
NOT LESS THAN 50% AND LESS THAN 60%	14 μs
NOT LESS THAN 60% AND LESS THAN 70%	16 μs
NOT LESS THAN 70%	ERROR

(EMISSION CURRENT CONSTANT 10mA)

FIG. 14

WHITE-TO-BLACK RATIO	EMISSION CURRENT
LESS THAN 30%	ERROR
NOT LESS THAN 30% AND LESS THAN 40%	10mA
NOT LESS THAN 40% AND LESS THAN 50%	12mA
NOT LESS THAN 50% AND LESS THAN 60%	14mA
NOT LESS THAN 60% AND LESS THAN 70%	16mA
NOT LESS THAN 70%	ERROR

(EMISSION TIME CONSTANT 10 μs)

FIG. 15A

Y TONER OUTPUT SIGNAL

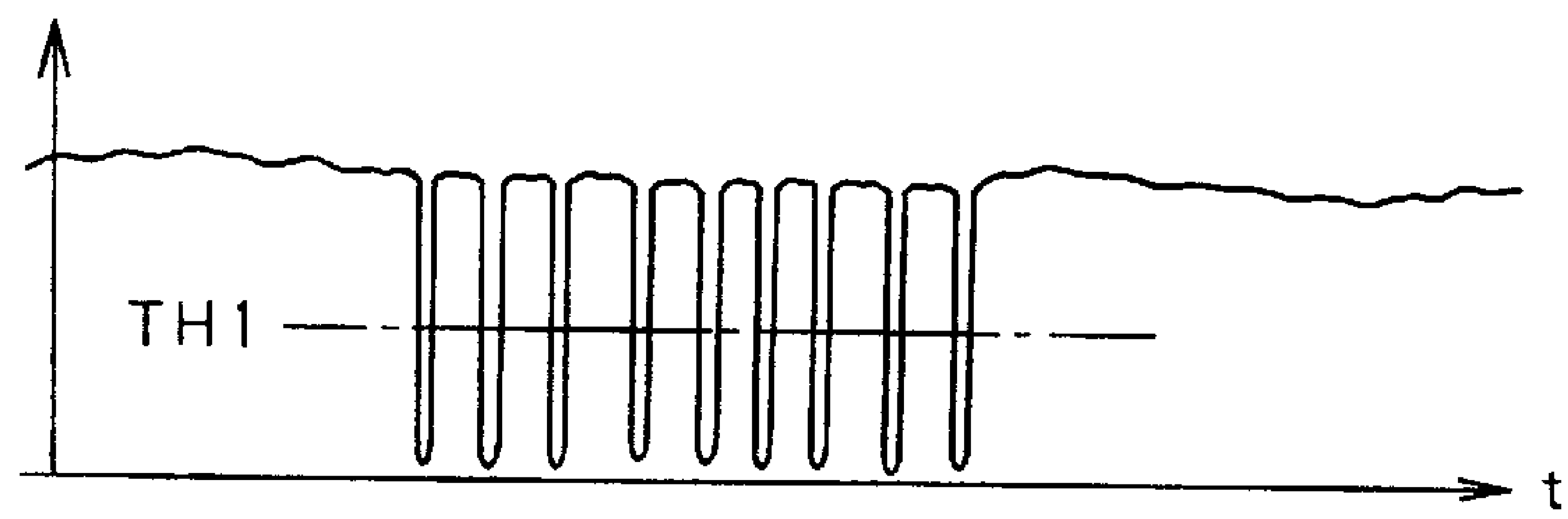


FIG. 15B

M TONER OUTPUT SIGNAL

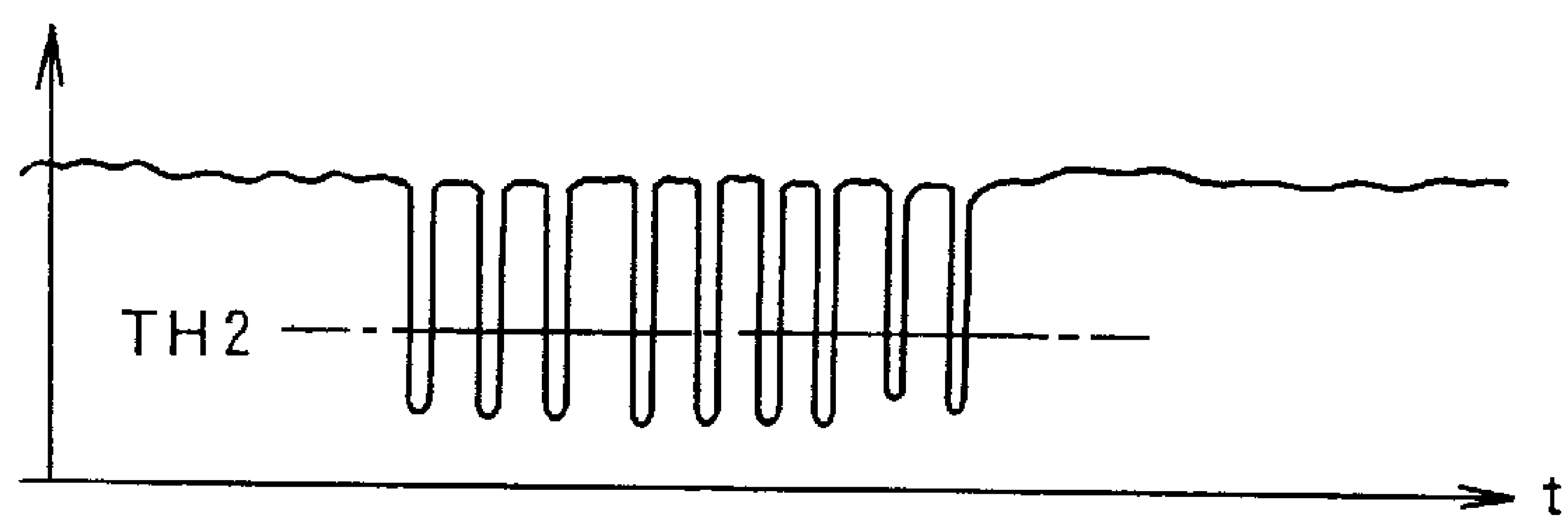


FIG. 15C

C TONER OUTPUT SIGNAL

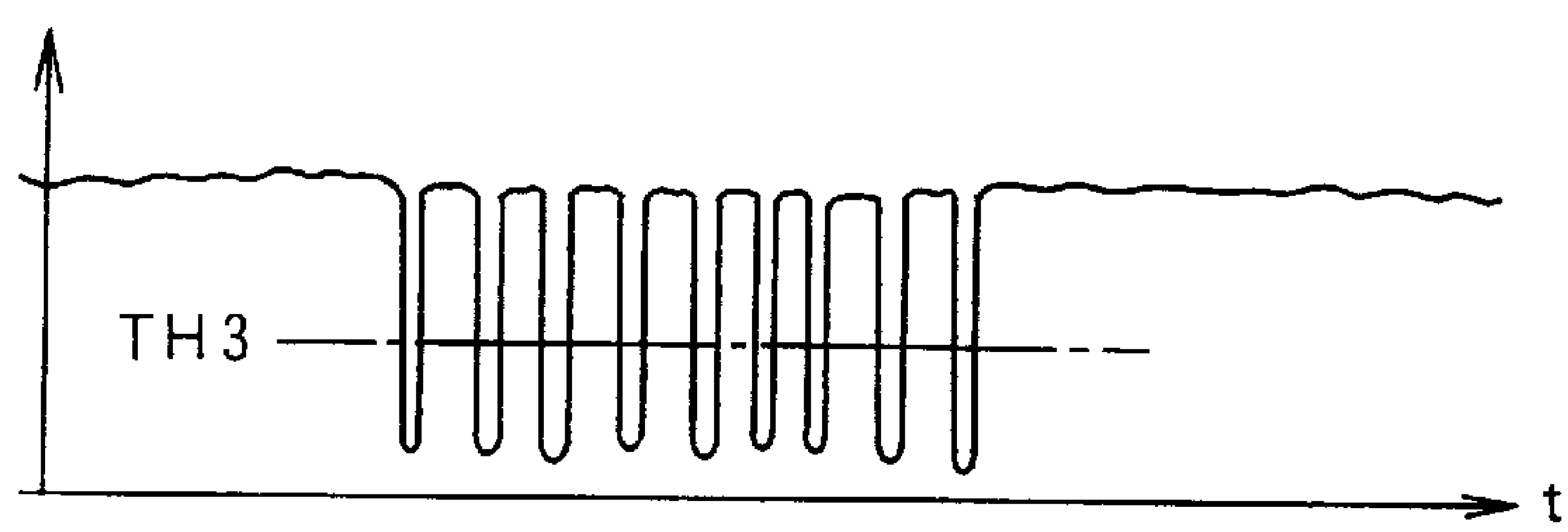


FIG. 15D

K TONER OUTPUT SIGNAL

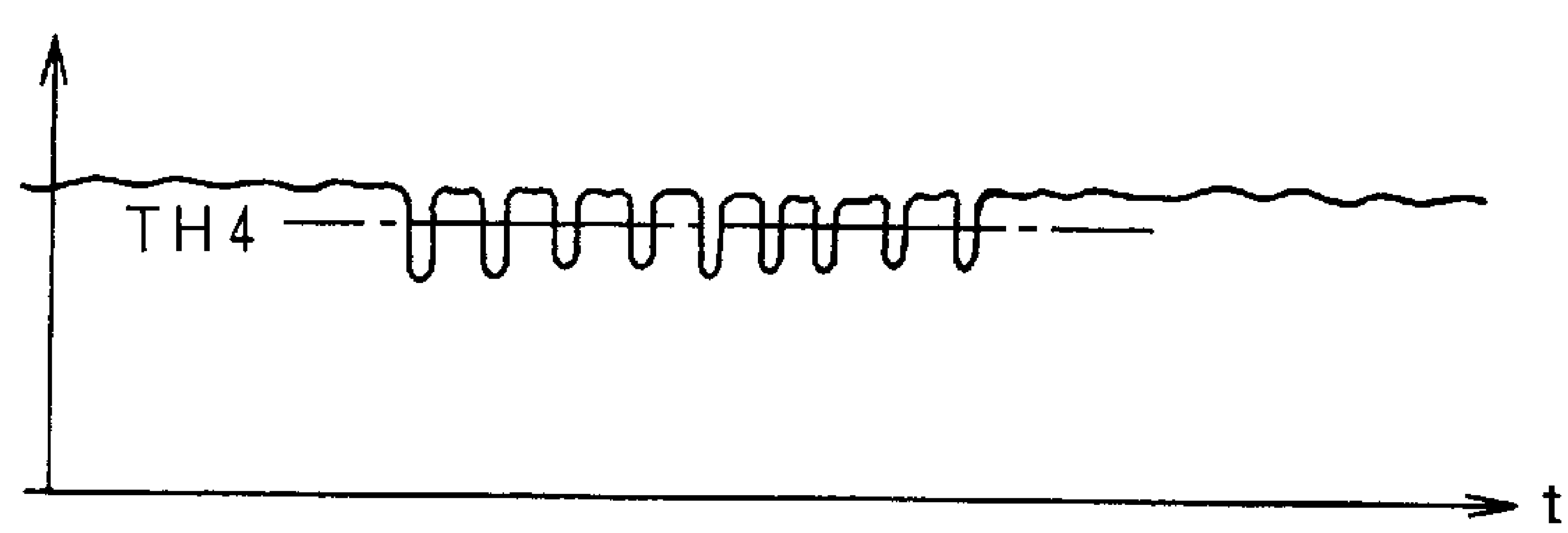
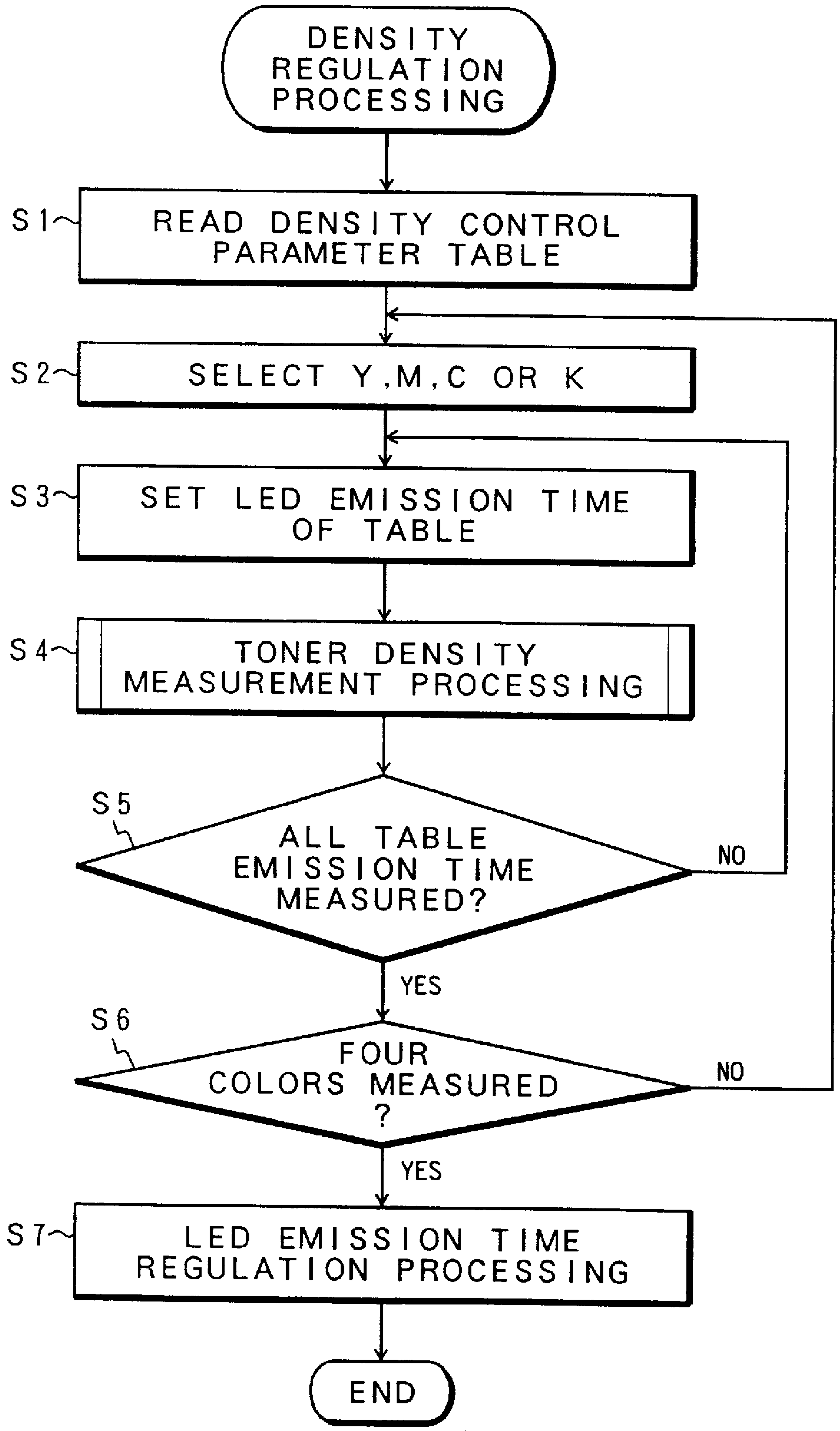
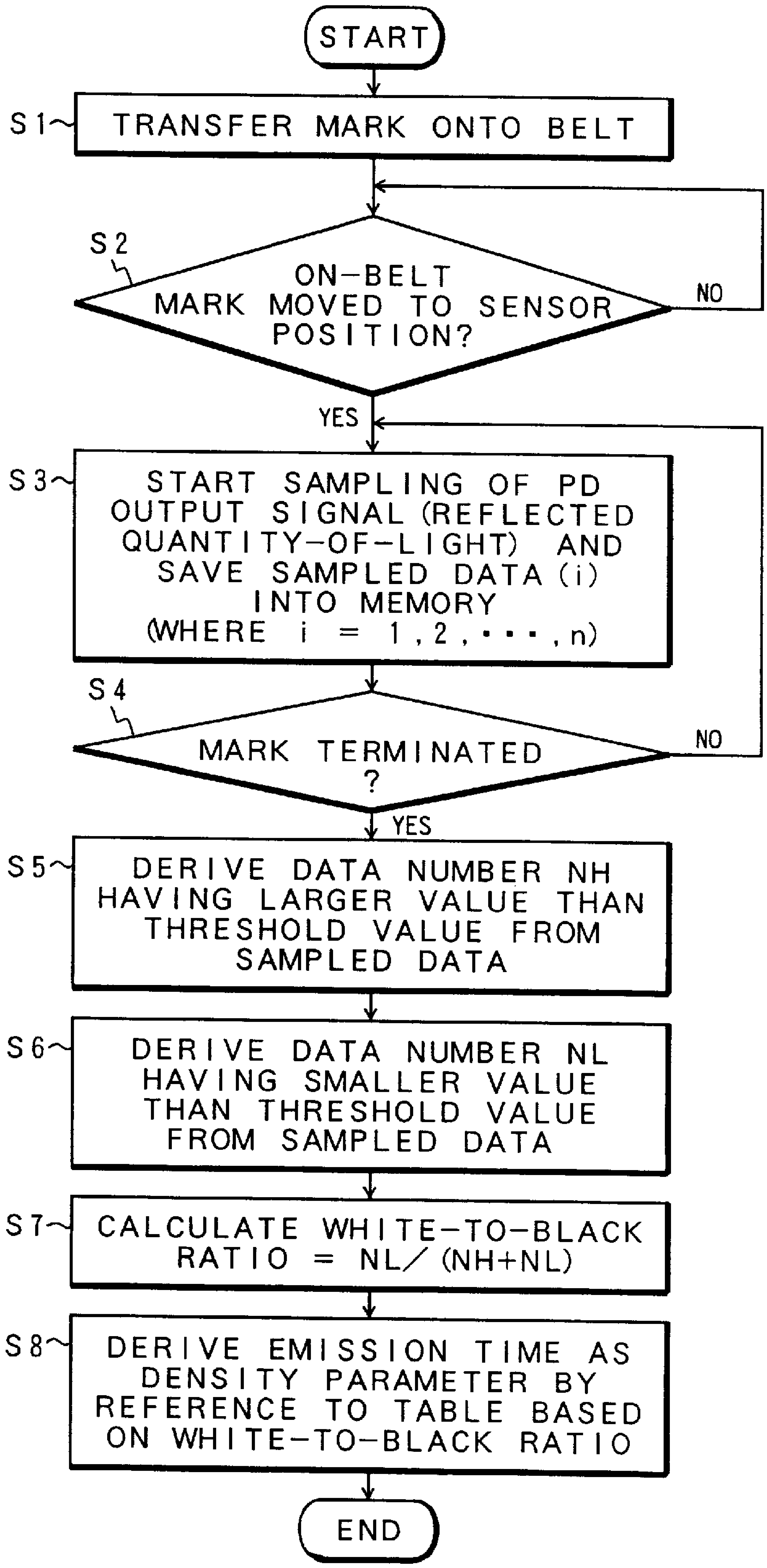


FIG. 16



DENSITY REGULATION PROCESSING
S1
READ DENSITY CONTROL PARAMETER TABLE
S2
SELECT Y,M,C OR K
S3
SET LED EMISSION TIME OF TABLE
S4
TONER DENSITY MEASUREMENT PROCESSING
S5
ALL TABLE EMISSION TIME MEASURED?
NO
YES
S6
FOUR COLORS MEASURED ?
NO
YES
S7
LED EMISSION TIME REGULATION PROCESSING
END

FIG. 17


START
S1
TRANSFER MARK ONTO BELT
S2
ON-BELT MARK MOVED TO SENSOR POSITION?
NO
YES
S3
START SAMPLING OF PD OUTPUT SIGNAL (REFLECTED QUANTITY-OF-LIGHT) AND SAVE SAMPLED DATA (i) INTO MEMORY (WHERE i = 1, 2, ・・・, n)
S4
MARK TERMINATED ?
NO
YES
S5
DERIVE DATA NUMBER NH HAVING LARGER VALUE THAN THRESHOLD VALUE FROM SAMPLED DATA
S6
DERIVE DATA NUMBER NL HAVING SMALLER VALUE THAN THRESHOLD VALUE FROM SAMPLED DATA
S7
CALCULATE WHITE-TO-BLACK RATIO = NL/(NH+NL)
S8
DERIVE EMISSION TIME AS DENSITY PARAMETER BY REFERENCE TO TABLE BASED ON WHITE-TO-BLACK RATIO
END

PRINTING APPARATUS AND TONER DENSITY MEASURING METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a printer for printing full color images through a superposed transfer of different color images by use of a plurality of electrostatic recording units equipped with an electrophotographic record printing function, and to a toner density measuring method for use therein. More particularly, the present invention relates to a printer in which the toner density is measured by optically detecting Y, M, C and K toners transferred onto the surface of a conveyance belt, as well as to a toner density measuring method for use therein.

2. Description of the Related Arts

In the conventional color printers using electrophotographic recording, four electrostatic recording units for black (K), cyan (C), magenta (M) and yellow (Y) are arranged in tandem in the direction where record sheets are conveyed. The electrostatic recording units for four colors each optically scan a photosensitive drum on the basis of image data to form a latent image thereon, develop the latent image with a color toner in the developing device, and thereafter transfer the toner image onto record sheets being conveyed at a constant speed, in a superposed manner in the order of yellow (Y), magenta (M), cyan (C) and black (K), and finally perform a thermal fixation of the transferred image through a fixing device. It is necessary for the printers having Y, M, C and K electrostatic recording units arranged in tandem in the record sheet conveying direction to reduce the positional offset of the toner image transferred onto the record sheets in motion by each electrostatic recording unit to thereby enhance the color matching accuracy in order to improve the color printing quality. To this end, such tandem-type printers perform a color matching process in which a toner mark is transferred onto the surface of the conveyance belt upon the power on or the cover opening or closing, the toner mark being read by e.g., a sensor to vary the write timing of the LEDs or laser diodes making up an exposure device to thereby regulate the color drift and the toner density.

The conventional printers use a sensor as depicted in FIG. **1** to detect the toner density. The sensor designated at **104** comprises an LED lamp **106** for issuing a spot light of the order of 8 millimeters in diameter on the surface of the belt **108** and a photodiode **112** for receiving a diffusely reflected light from the toner **110** lying on the spot light region. In the sensor circuit, as shown in FIG. **2** the diffusely reflected light from the toner **110** on the belt surface **108** originating from the LED lamp **106** is received by the photodiode **112** and thereafter amplified by an amplifier **114** having a negative feedback circuit composed of a resistor **116**, and further amplified by amplifiers **118** and **120**, sampled by an A/D converter **122** and entered as light reception data into an MPU **124** to determine the density control parameter such as the emission time of the exposure LEDs corresponding to the toner density from the light reception data. The toner density regulation includes setting the density control parameter which is optimum for the default, e.g., the optimum emission time in four stages as 8 μs, 13 μs, 18 μs and 23 μs, transferring the toner in each emission time to determine the density, converting the measured density into the emission time to obtain a lag relative to the optimum emission time, and correcting the optimum emission time from this lag to regulate the toner density upon the printing to the optimum value.

However, such a conventional method for measuring the toner density from the diffusely reflected light from the toner transferred onto the belt surface has a deficiency that the Y, M and C color toners have a different reflectance from that of the K black toner so that the density of black toner cannot be detected. For example, assume as in FIG. **3**A that slanted lines are transferred at a constant pitch by the LED exposure device, with the LEDs' emission current unvaried and with the emission time varied to e.g., 8, 13, 18 and 23 to increase the line width so that toner transfer patterns **128**, **130**, **132**, **134** are transferred onto the belt surface in the order of thinness. When this toner transfer pattern is read by the sensor **104** of FIG. **1**, light reception signals corresponding to the toner density (amount of adhesion of toner) are obtained as in FIG. **3**B in the case of the Y, M and C color toners. More specifically, in the case of the Y, M and C color toners although there exists a slight difference thereamong, when a light from the LED lamp **106** is irradiated on the toners, the light diffusely reflected on the Y, M and C toners impinges on the photodiode **112**. At that time, a higher density with a large amount of adhesion of toner results in a larger quantity-of-light diffusely reflected on the toner, whereas a lower density with a small amount of adhesion of toner results in a smaller quantity-of-light diffusely reflected on the toner, whereby the Y, M and C toner density can be measured from the magnitude of the diffusely reflected light received by the photodiode **106** as shown by way of an example in FIGS. **3**A and **3**B, where toner marks **128**, **130**, **132** and **134** with progressively increasing density being respectively shown to have increasing magnitude of output signals **136**, **138**, **140** and **142**. However, the K black toner exceptionally has a high light absorbance and presents an extremely less variation of the diffusely reflected light arising from the amount of adhesion of toner as shown in FIG. **5**C. For this reason, a problem is posed that the sensor of FIG. **1** is unable to determine the density of the K black toner. On the contrary, in order to obtain only the K black toner density, it will suffice to irradiate the toner transfer surface with the LED lamp to receive the regularly reflected light therefrom, where the higher the toner density, the lower is the reflection, as shown by way of an example where the toner mark density is increased from signal **136** to **138** in FIG. **3**B, but the reflection output signal is decreased to a lower output signal level **144** in FIG. **3**C. However, this approach may be problematic in that there is a need to provide two different types of sensors, i.e., the sensor for black toner and the sensor for color toners as shown in FIG. **1**, which leads to a complicated sensor arrangement, sensor circuit and sensor structure, resulting in a rise of costs.

In recent years, as shown in FIG. **4**, a sensor **146** is provided with a photodiode **112** for receiving a diffusely reflected light from the LED lamp **106** and with a photodiode **148** for receiving a regularly reflected light therefrom to provide an integrated sensor structure allowing the simultaneous measurement of the Y, M and C color toners and K black toner. However, this sensor also necessitates the two photodiodes **112** and **148** for the black toner and for color toners, with the need for two reception light amplifying circuits of FIG. **1**. Thus, the same deficiency still remains left as in the case of use of the two sensors for black toner and the color toners excepting that the single sensor placement is sufficient.

SUMMARY OF THE INVENTION

According to the present invention there are provided a printing apparatus capable of measuring the density of both Y, M and C color toners and K black toner by the combination of a single light emitting element and a single light receiving element and equipped with a sensor function having a simple structure and circuit configuration and easy to install, and a toner density measuring method for use therein.

The present invention is directed to a printing apparatus comprising a belt unit which conveys record sheets on a belt at a constant speed, the record sheets being electrostatically adhered to the surface of the belt; and a plurality of electrostatic recording units arranged in the direction of conveyance of the record sheets, the electrostatic recording units forming a latent image corresponding to image data through an optical scanning on a photosensitive drum in rotation by an exposure device, the electrostatic recording units developing the latent image with a toner component of different color, to thereafter transfer the developed image onto the record sheets lying on the surface of the belt. The present invention provides such a printing apparatus with a toner mark transfer unit which transfers a halftone pattern onto the surface of the belt by use of the plurality of electrostatic recording units; a sensor unit which optically reads the halftone pattern transferred onto the surface of the belt; and a toner density measurement unit which measures the toner density on the basis of the ratio of a reflected light from a toner bearing portion to a reflected light from a toner free portion in a read signal of the halftone pattern from the sensor unit.

The toner transfer unit transfers a transverse line pattern or a slanted line pattern on the surface of the belt, the line width of the transverse line pattern or of the slanted line pattern varying in proportion to the density. The toner density measurement unit samples at a predetermined cycle a sensor output signal of the transverse line pattern or of the slanted line pattern transferred onto the surface of the belt, the toner density measurement unit figuring out as the toner density a white-to-black ratio NL/(NL+NH) from the number NH of sampled data having a higher value than a predetermined threshold value and from the number NL of sampled data having a lower value than the threshold value. The toner density measurement unit refers to table information previously defining the relationship between the white-to-black ratio and a density control parameter, to determine the density control parameter corresponding to the amount of adhesion of toner. In this case, the density control parameter to be determined by the toner density measurement unit is the emission time when the amount of current flowing per dot of the exposure device is constant or the amount of current when the emission time per dot of the exposure device is constant. The the sensor unit includes a condenser lens through which a light from a laser diode impinges on the belt transfer surface in the form of a spot light of the order of several tens of microns, the sensor unit when no toner components adhered providing as its output a signal of a reflected light by irradiation of the spot light, the reflected light being received by a light reception element arranged in the direction of a predetermined output angle, the sensor unit when toner components adhered providing as its output a signal of a light attenuated due to scattering by irradiation of the spot light, the attenuated light being received by the light reception element. The sensor unit has an incident angle θ**1** from the laser diode relative to the belt surface and an output angle θ**2** from the belt surface relative to the light receiving element, the incident angle θ**1** and the output angle θ**2** being set to the range of 60 to 80 degrees, preferably to the vicinity of 70 degrees. In this manner, the present invention allows the toner density to be measured from the line width substantially proportional to the amount of adhesion of toner of the transverse line pattern or the slanted line pattern transferred in the form of the halftone pattern, whereby it is possible to obtain the toner density through secure determination of the line width from the sensor read signal with possible attenuated quantity-of-light for not only the YMC color toners but also for K black toner without relying on the toner reflectance as in the conventional toner density measurement based on the reception signal of a reflected light by the toner diffuse reflection or regular reflection. It is also possible to measure the K black toner and the Y, M and C color toners by the same sensor, the same circuit and the same algorithm, with the high resistance to the analog noises and acquisition of stably high measurement accuracy by virtue of the detection of the line width. Furthermore, the sensors for the toner density detection can be of the same sensor structure as that of the sensor for correcting the toner positional offset which similarly effects its work through the toner mark transfer on the belt surface, whereby a single sensor can be used for both the toner positional offset and the toner density measurement to thereby reduce the costs.

The present invention further provides a toner density measuring method for a printing apparatus having a belt unit which conveys record sheets on a belt at a constant speed, the record sheets being electrostatically adhered to the surface of the belt, and having a plurality of electrostatic recording units arranged in the direction of conveyance of the record sheets, the electrostatic recording units forming a latent image corresponding to image data through an optical scanning on a photosensitive drum in rotation by an exposure device, the electrostatic recording units developing the latent image with a toner component of different color, to thereafter transfer the developed image onto the record sheets lying on the surface of the belt, the method comprising the steps of transferring a halftone pattern onto the surface of the belt by use of the plurality of electrostatic recording units;

optically reading the halftone pattern transferred onto the surface of the belt, by use of a sensor unit; and measuring the toner density on the basis of the ratio of a reflected light from a toner bearing portion to a reflected light from a toner free portion in a read signal of the halftone pattern.

The details of the toner density measuring method are substantially the same as those of the printing apparatus.

The above and other objects, aspects, features and advantages of the present invention will become more apparent from the following detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an explanatory diagram of a conventional sensor receiving a toner diffuse reflection light;

FIG. **2** is an explanatory diagram of a conventional sensor circuit;

FIGS. **3**A to **3**C are explanatory diagrams of output signals for YMC color toners and K black toner in the conventional sensor;

FIG. **4** is an explanatory diagram of the conventional sensor performing integrated diffuse reflection light detection and regular reflection light detection;

FIG. **5** is an explanatory diagram of the internal structure of a printing apparatus in accordance with the present invention;

FIGS. **6**A and **6**B are block diagrams of the hardware configuration of the present invention;

FIG. **7** is an explanatory diagram of a sensor unit of the present invention;

FIG. **8** is an explanatory diagram of a specific embodiment of FIG. **7**;

FIG. **9** is a block diagram of a toner density measurement function in accordance with the present invention;

FIGS. **10**A and **10**B are explanatory diagrams of a halftone pattern transferred as a toner mark in the present invention;

FIGS. **11**A to **11**C are explanatory diagrams of the toner adhesion amount and a toner mark read signal;

FIGS. **12**A to **12**C are explanatory diagrams of signal processing for determining a white-to-black ratio from the toner mark read signal;

FIG. **13** is an explanatory diagram of a density control parameter table of FIG. **9** with respect to the emission time;

FIG. **14** is an explanatory diagram of the density control parameter table of FIG. **9** with respect to the emission current;

FIGS. **15**A to **15**D are explanatory diagrams of Y, M, C and K toner mark read signals and threshold values;

FIG. **16** is a flowchart of density regulation processing based on FIG. **7**; and

FIG. **17** is a flowchart of toner density measurement processing of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **5** shows the internal structure of a printing apparatus having a toner density measurement function in accordance with the present invention. The interior of an apparatus body generally designated at **10** is provided with a conveyance belt unit **11** for conveying a record medium, e.g., record sheets, the conveyance belt unit **11** having rotatably an endless belt **1** made of a flexible dielectric material, e.g., appropriate synthetic resin material. The endless belt **12** is stretched over four rollers **22-1**, **22-2**, **22-3** and **22-4**. The roller **22-1** functions as a driving roller having a drive mechanism not shown by means of which the endless belt **12** is driven clockwise as indicated by an arrow at a constant speed, e.g., at 54 mm/s. The driving roller **22-1** is driven by motor **25** and serves also as an AC elimination roller for eliminating electric charge from the endless belt **12**. The roller **22-2** functions as a driven roller which serves also as a charging roller for imparting electric charge to the endless belt **12**. Both the rollers **22-3** and **22-4** act as guide rollers which are disposed in the vicinity of the driver roller **22-1** and the driven roller **22-2**, respectively. The upper running part of the endless belt **12** forms a record sheet moving path between the driven roller **22-2** and the driving roller **22-1**. A stack of record sheets are stored in a hopper **14** such that they are delivered one by one from the uppermost one in the hopper **14** by means of a pickup roller **16**. The record sheets picked up by the pickup roller **16** pass through a record sheet guide passage **18**, and are led from the driven roller **22-2** side of the endless belt **12** into the record sheet moving path of the endless belt **12** by means of a pair of record sheet feed rollers **20** and finally discharged from the driving roller **22-1**. The endless belt **12** being charged by the driven roller **22-2**, the record sheets electrostatically adhere onto the endless belt **12** when they are led from the driven roller **22-2** side into the record sheet moving path, thereby preventing any positional offset of the record sheets in motion. On the other hand, the discharge side driving roller **22-1** serves as a charge elimination roller so that the endless belt **12** is cleared of electric charge at the portion in contact with the driving roller **22-1**. For this reason, the record sheets are cleared of electric charge upon the passage through the driving roller **22-1** so that they are readily peeled away and discharged from the endless belt **12** without being entangled in the belt underside. The interior of the apparatus body **10** is provided with four electrostatic recording units **24-1**, **24-2**, **24-3** and **24-4** for Y, M, C and K which are arranged in series or tandem in the mentioned order from upstream toward downstream along the record sheet moving path on the belt upper side of the endless belt **12** defined between the driven roller **22-2** and the driving roller **22-1**.

The electrostatic recording units **24-1** to **24-4** have substantially the same structure excepting the use of yellow toner component (Y), magenta toner component (M), cyan toner component (C) and black toner component (K), respectively, as a developing agent. For this reason, the electrostatic recording units **24-1** to **24-4** transfer yellow toner images, magenta toner image, cyan toner image and black toner image in sequence and in a superposed manner on top of the record sheets moving along the record sheet moving path on the upper side of the endless belt **12**, to form full color toner images thereon. As is well known, the electrostatic recording units **24-1** to **24-4** each include a precharger, an array of LEDs acting as an exposure device, a toner developing unit, an electrostatic transfer roller driven by a motor generally designated as motors **15-1**, **15-2**, **15-3** and **15-4**, and a toner cleaner, which are arranged around a photosensitive drum, to perform electrostatic photoprinting in accordance with an electrophotographic process. After the formation thereon of full color images as a result of superposed transfer of four color toners Y, M, C and K by the electrostatic recording units **24-1** to **24-4**, the record sheets are delivered from the driving roller **22-1** to a heat roller type thermal fixing device **26**, for thermal fixation of the fill color images onto the record sheets. After the completion of the thermal fixation, the record sheets pass through guide rollers and are stacked on a stacker **27** provided on top of the apparatus body. A pair of sensors **28-1** and **28-2** are arranged in the direction orthogonal to the belt moving direction in such a manner as to confront the undersurface of the endless belt **12** in the conveyance belt unit **11**, although only the sensor **28-1** closer to the viewer is visible in the state of FIG. **5**. The pair of sensors **28-1** and **28-2** detect a toner mark for color drift regulation transferred to the endless belt **12** and optically read a toner mark for toner density measurement in the density regulation. The color matching processing for the color drift regulation and the density regulation in this printing apparatus is carried out when the printing apparatus is activated or when the cover is opened or closed upon the toner replacement of the electrostatic recording units **24-1** to **24-4**.

FIGS. **6**A and **6**B are block diagrams of the hardware configuration of the printing apparatus in accordance with the present invention. The hardware of the printing apparatus of the present invention is constructed of an engine **30** and a controller **32**. The engine **30** comprises a mechanical controller **34** for providing control operations of the printing mechanisms such as the conveyance belt unit **11** and the electrostatic recording units **24-1** to **24-4** of FIG. **5**. The mechanical controller **34** is associated with an MPU **36** for sensor processing which executes the toner density measurement processing in accordance with the present invention upon the density regulation processing. The MPU **36** for sensor processing accepts detection signals from the pair of sensors **26-1** and **26-2** disposed below the endless belt **12**, in the form of digital data sampled by A/D converters **38-1** to

38-2. The mechanical controller **34** is connected via an engine connector **40** to the controller **32** side. Exclusively shown herein as the printing mechanisms provided in the engine **30** are the endless belt **12** and sensors with LED arrays **28-1**, **28-2**, **28-3** and **28-4** acting as the exposure devices provided in the respective electrostatic recording units for Y, M, C and K. The controller **32** comprises an MPU **42** for controller. A personal computer **62** for example as the host is connected to the MPU **42** for controller by way of an interface processing unit **44** and a controller connector **46**. The personal computer **62** is provided with a driver **66** for printing color image data provided from any desired application program **64**, the driver **66** being connected via a personal computer connector **68** to the controller connector **46** of the controller **32**. The MPU **42** for controller of the controller **32** is provided with image memories **52-1**, **52-2**, **52-3** and **52-4** for expanding for storage into pixel data (dot data) Y, M, C and K image data transferred from the personal computer **62**. On the other hand, the MPU **42** for controller is connected to the engine **30** by way of an interface processing unit **48** and a controller connector **50** so that the interface processing unit **48** can accept positional offset information and toner density information detected by the engine **30** side to perform color matching processing containing the positional offset correction and toner density correction for each of the toner image data expanded into the image memories **52-1** to **52-4**. The MPU **42** for controller is provided with an addressing unit **54** for performing addressing upon the expansion of the respective color pixel data into the image memories **52-1** to **52-4**. The addressing unit **54** has also a function for performing address conversion for positional offset correction based on the positional offset information provided from the engine **30** side.

FIG. **7** is an explanatory diagram of a sensor **28-1** disposed below the endless belt **12** shown in the engine **30** side of FIGS. **6**A and **6**B. The sensor **28-1** comprises a housing **70** facing the underside of the endless belt **12**, a laser diode **72** acting as a light source and a photodiode **80** acting as a light receiving element, the two diodes being arranged within the housing **70**. The laser diode **72** issues laser beams having a wavelength of e.g., 780 nm and condenses the beams by an image forming lens **74** positioned on an incident optical axis **75**, to form a minute beam spot on an image forming position **76** on the endless belt **12**. The diameter of the beam spot of the laser beams irradiated on the image forming position **76** is reduced to about several tens of micrometers for example. The photodiode **80** is positioned on an reflected optical axis **78** from the image forming position **76**. The incident angle θ1 of the incident optical axis **75** relative to the belt surface is equal to the output angle θ2 of the reflected optical axis **78** relative thereto. The incident angle θ1 and the output angle θ2 are set to the range of 60 to 80 degrees for example, and preferably to 70 degrees as a result of experiments of the inventors of this application. In the relationship between the incident optical axis **75** equipped with the laser diode **72** and the image forming lens **74** and the reflected optical axis **78** equipped with the photodiode **80**, a minute beam spot through the image forming lens **74** from the laser diode **72** is irradiated on the image forming position **76**, the direction of regular reflection from which is defined as the reflected optical axis on which is placed the photodiode **80** as the light receiving element. For this reason, in the absence of toner transferred on the belt **12**, the beam spot from the laser diode **72** is regularly reflected on the belt surface, with the regularly reflected beam impinging on the photodiode **80** to issue a light reception signal to a sensor circuit unit **82**. In case of transfer of a toner mark onto the belt **12** for toner density measurement, the movement of the transferred toner mark to the image forming position **76** may cause the irradiated beam to be diffusely reflected by the toner particles as a result of irradiation of the beam spot reduced from the laser diode **72**, whereupon the reflected quantity-of-light impinging on the photodiode **80** arranged on the reflected optical axis **78** is reduced so that the light reception signal lowers as compared with the absence of the toner.

FIG. **8** is a sectional view of a specific embodiment of the sensor **28-1** of FIG. **7**. The laser diode **72** is disposed on the left side in the housing **70**, the image forming lens **74** with a collimator being disposed in front of the laser diode **72**. The beams of light from the laser diode **72** are condensed through the image forming lens **74** so that a minute beam spot is formed with the incident angle θ1 at the image forming position **76** on the belt surface **12**. The photodiode **80** is disposed by way of a condenser lens **75** in the optical axis direction with the output angle θ2 from the image forming position **76** on the belt **12**. In the sensors of the present invention, for the toner density measurement the toner marks are transferred onto the surface of the belt **12** using the K, C, M and Y toners in sequence so that the toner marks are detected by the sensors. In this case, the toner marks transferred onto the surface of the belt **12** are unfixed toners substantially without any luster, with the result that the irradiation of the minute spot onto the unfixed transferred toners will cause a diffuse reflection to reduce the quantity-of-light received. Herein, the endless belt **12** is guided along a guide plate **77** positioned on the back side. This allows a scattered light to strike on the photodiode **80** as a result of reflection on the guide plate **77** positioned on the back side of the image forming position **76** on which the beam spot from the laser diode **72** is formed, the scattered light resulting in a noise light. Thus, the guide plate **77** positioned behind the endless belt **12** is provided with a transmitting hole **79** located at the portion from which the noisy scattered light may be generated around the image forming position **76**, thereby preventing the occurrence of the noise light by the reflection on the guide plate **77**.

FIG. **9** is an explanatory diagram of a toner density measuring function provided in the printing apparatus of the present invention, showing in conjunction with the sensor circuit unit. The MPU **36** for sensor processing comprises a density regulation processing unit **100** which includes a toner mark transfer unit **101**, a toner density measurement unit **102** and a density control parameter table **104**. The MPU **36** for sensor processing activates the color matching processing at the time of power on of the printing apparatus or upon the cover opening or closing attendant on the toner replacement to perform the correction of the color drift arising from the toner mark transfer, after which it performs the toner density measurement processing of the present invention. Available as the toner color drift correction of the printing apparatus in the present invention are the ones disclosed in U.S. Pat. No. 5,946,523 or U.S. patent Ser. No. 09/041,006.

The toner mark transfer unit **101** provided on the MPU **36** for sensor processing drives the electrostatic recording units **24-1** to **24-4** by way of the mechanical controller **34** at the time of toner density measurement and transfers halftone patterns with different densities on the belt surface at the detection position by the sensor **28-1** of the endless belt **12**, using the control parameter of the density control parameter table **104** set as default for each toner, e.g., using the light emission time which has been set into four stages.

FIG. **10**A shows a halftone pattern for toner density measurement transferred onto the belt surface by the toner mark transfer unit **101**, in which a transverse lines is transferred in the horizontal scanning direction orthogonal to a sensor detection line **35**, the transverse line being iterated at a constant pitch in the vertical scanning direction to form a transverse line pattern transferred. More specifically, the electrostatic recording units **24-1** to **24-4** use the LED arrays **28-1** to **28-4** as the exposure devices as shown in FIGS. **6**A and **6**B, and hence the light emission timing in the vertical scanning direction of the LED arrays aligned in the horizontal scanning direction is controlled to e.g., "1on3off" so that the halftone pattern composed of the transverse line pattern as in FIG. **10**A is transferred. The thickness of the transverse line in this transverse line pattern can be varied by altering the light emission time in the case of a constant LED emission current. In other words, a shortened emission time results in a reduced line width, whereas an extended emission time results in an increased line width. The reduced line width represents a lower toner density and the increased line width represents a higher toner density. This means that the transverse line pattern line width defines the density area gradation in the halftone pattern.

FIG. **10**B shows another embodiment of the halftone pattern for use in the toner mark transfer unit **101**, in which a slanted line pattern is transferred which is slanted in the horizontal scanning direction and in the vertical scanning direction. In the transverse line pattern of FIG. **10**A and the slanted line pattern of FIG. **10**B, the halftone pattern required for the toner density measurement of the present invention can be the pattern in which the toner bearing portion and the toner free portion of the halftone pattern are iterated at a constant pitch in the direction of the sensor detection line **35**, when viewed from the sensor detection line **35**, whereupon the toner bearing portion and the toner free portion can equally be detected at a constant pitch when viewed from the sensor detection line irrespective of the transverse line pattern or the slanted line pattern.

Referring again to FIG. **9**, the toner density measurement unit **102** provided in the MPU **36** for sensor processing optically reads by the sensor **28-1** the toner mark of a halftone pattern composed of the transverse line pattern of FIG. **10**A or the slanted line pattern of FIG. **10***b* transferred on the belt surface by the toner mark transfer unit **101**, and derives the toner density from this read signal. The sensor circuit unit of the sensor **28-1** will first be described. The MPU **36** for sensor processing provides as its output control data whose emission time is controlled with its constant emission time to the A/D converter **84** at the time of toner density measurement, enters the control signal from the A/D converter **84** into the base of a transistor **86** to turn on it, and supplies the emission current to the laser diode **72** with a bias applied to a series circuit of the resistors **88** and **90**, for radiation of the laser beams. The laser beams from the laser diode **72** are reflected on the belt surface of the endless belt **12** so that a reflected light strikes on the photodiode **80** for the conversion into a light reception signal which in turn is inversion amplified by an operational amplifier **92** equipped with an input resistor **94** and a feedback resistor **95** and then is non-inversion amplified by an operational amplifier **96** equipped with an input resistor **97** and a feedback resistor **98**. The thus obtained light reception signal is sampled by the sampling clock in the A/D converter **38-1** and is fetched as the digital light reception data into the MPU **36** for sensor processing. The toner density measurement unit **102** drives the A/D converter **38-1** when the toner mark of the halftone pattern of FIG. **10**A or FIG. **10***b* transferred on the belt surface by the toner mark transfer unit **101** arrives at the detection position of the sensor **28-1**, to covert a light reception signal from the operational amplifier **96** at that time into light reception data for the storage in the memory **106**. On the basis of the read signal stored in the memory **106**, the toner density measurement unit **102** acquires density control parameters corresponding to the toner density, e.g., LED emission time or emission current by reference to the density control parameter table **104**, from the ratio of the reflected light from the toner bearing portion and the reflected light from the toner free portion, i.e., from the ratio of the light reception signal.

FIGS. **11**A to **11**C are explanatory diagrams of the read signal of the halftone pattern detected by the sensor **28-1** of FIG. **9**. FIG. **11**A shows the toner free case in which substantially a constant level of light reception signal is obtained. FIG. **11**B shows a read signal of the halftone pattern with a small amount of toner adhesion, in which a reduced level of light reception signal is obtained due to the scattering of the light at the toner adhered transverse line position if the pattern of 10 transverse lines is transferred for example. FIG. **11**C shows the read signal in the case of a large amount of toner adhesion, i.e., in the case of large line width of the transverse line pattern of FIG. **10**A, in which a reduced level of light reception signal is obtained corresponding to the toner adhered line width. In the light reception signal corresponding to the magnitude of the amount of toner adhesion of FIGS. **11**B and **11**C, the toner mark read period is the time T from the first signal trailing edge up to the last signal leading edge, the toner mark read period T containing **10** signal level reduced portions. Let **T1** be the period during which the signal level is reduced due to the adhesion of the toner of FIG. **11**B, and let T**2** be the period during which the signal level is reduced due to the adhesion of the toner of FIG. **11**C. If the number of times of reduction is 10, then the total of the toner adhesion periods results in 10×T**1** and 10×T**2**, respectively. For this reason, from the ratio of the total of the toner adhesion periods to the toner mark detection period T, the white-to-black ratio WBR indicative of the amount of toner adhesion per unit area can be figured out. That is, the white-to-black ratio WBR is given for FIG. **11**B as

$$WBR=\{(10\times T1)/T\}\times 100[\%]$$

and for FIG. **11**C as

$$WBR=\{(10\times T2)/T\}\times 100[\%]$$

In the present invention, the toner density control parameters are determined from the white-to-black ratio WBR obtained from the toner mark detection periods and the toner adhesion periods.

FIGS. **12**A to **12**C are explanatory diagrams of the white-to-black ratio calculation processing actually effected in the present invention. FIG. **12**A shows an output signal from the sensor, whose signal level is lowered correspondingly to the transverse lines of the toner adhesion for example during the toner mark period T. Then, of this sensor output signal, use is made of a sampling gate corresponding to the sampling pulse of FIG. **12**B and to the toner detection feedback of FIG. **12**C so that the sensor output signal level at that time is A/D converted for the storage in the memory for each sampling pulse by the operations of the A/D converter **38-1** in synchronism with the sampling pulse. Then, of the sensor output signal after the storage in the memory, a threshold value TH is set which is substantially intermediate between the toner free high level and the toner present low level. The threshold value TH is compared with the sampling data of the sampling gate periods stored in the memory so as to obtain the number NH of the sampling data having the value not less than the threshold value TH and the number NL of the sampling data having the value less than the threshold value TH. After the acquisition of the data number NH not less than the threshold value and the data number NL less than the threshold value in this manner, the white-to-black ratio WBR indicative of the toner density of the read pattern is obtained from

$$WBR=\{NL/(NH+NL)\}\times100[\%] \quad (1)$$

The white-to-black ratio WBR obtained in FIG. **12A** becomes same as the white-to-black ratio WBR obtained from the sum total of the toner mark period T and the toner present period in FIGS. **11B** and **11C**.

FIG. **13** is an explanatory diagram of the density control parameter table **104** of FIG. **9**, in which previously entered at four stages as optimum default values are relations between the white-to-black ratio WBR (%) calculated from the expression (1) and the emission time in case of a constant emission current of LEDs in the LED array. The optimum emission times 10 μs, 12 μs, 14 μs and 16 μs classified into four stages of the density control parameter table **104** are used for the exposure of the halftone pattern transferred on the belt surface upon the toner density measurement. After the calculation of the white-to-black ratio WBR by the toner measurement unit **102** from the read signal of the sensor **28-1**, reference is made to the density control parameter table **104** of FIG. **13** for the conversion into the emission time using the measured density as the density control parameter. FIG. **14** is another explanatory diagram of the density control parameter table **104** for use in the present invention, in which entered is an emission current with the LED array emission time constant relative to the white-to-black ratio (%). Although FIGS. **13** and **14** show the example of the white-to-black ratio of 10% interval, 5% interval may be employed for further enhanced accuracy, i.e., any appropriate resolving power could be employed as needed.

FIGS. **15A** to **15D** show as a contrasted manner the sensor read signals obtained when the Y, M, C and K toner halftone patterns are transferred onto the belt surface. FIG. **15A** shows the Y toner sensor output signal, FIG. **15B** shows the M toner sensor output signal, FIG. **15C** shows the C toner sensor output signal and FIG. **15D** shows the K toner sensor output signal. When these toner sensor output signals are contrasted with one another, the Y toner presents the greatest signal reduction with a slightly smaller signal reduction of the M toner and the C toner. For this reason, as to the Y, M and C toners, the white-to-black ratio can be calculated from the sampling data with the threshold values TH1, TH2 and TH3 equal to substantially half of the signal level of the toner free case. On the contrary, as to the K toner sensor output signal, the signal attenuation at the toner portion is smaller than the Y, M and C toners although the white-to-black ratio can correctly be figured out from the sampling data by setting the threshold value TH4 to substantially intermediate between the toner free level and the toner present level. That is, in the present invention, due to the detection of the line width of the read signal of the halftone pattern by each toner transverse line pattern or slanted line pattern, the white-to-black ratio can be obtained indicative of the correct toner amount of adhesion, i.e., toner density through the detection of the signal reduced portion of the line width corresponding to the toner density, without being influenced by any level variation of the sensor output signals.

FIG. **16** is a flowchart of the density regulation processing in which the toner density measurement of the present invention is carried out. First, in step **S1** the density control parameter table **104** as in FIG. **13** is read. Then in step **S2** selection is made of e.g., Y toner as the toner to first be measured, and in step **S4** the first LED emission time 10 μs is set from the density control parameter table **104**. Then in step **S4**, the toner density measurement processing of the present invention is carried out. The details of the toner density measurement processing are shown in FIG. **7**. From this toner density measurement, the white-to-black ratio WBR is figured out of the halftone pattern transferred through the exposure with the set emission time 10 μs on the belt surface, and reference is made to the density control parameter table **104** to obtain the light emission time. Then in step **S5** a check is made to see if all the emission times of the table have been measured or not, and if negative, then the procedure goes to step **S3** to make a toner density measurement similarly by setting the next emission time. After the completion of the toner density measurement by the setting of all the emission times, it is checked in step **S6** whether the measurement of all the four colors has been completed, and if negative, then the procedure goes to step **S3** to select the next M toner to repeat the similar toner density measurement. After the completion of measurement of all the four colors, the procedure goes to step **S7** to perform the LED emission time regulation processing. The LED emission time regulation processing includes determining a time lag between the ideal emission time of the density control parameter table **104** and the measured emission time and correcting the table ideal emission time based on this time lag to obtain the emission time used for the actual printing. For example, the white-to-black ratio of 55% is obtained as the result of measurement by the exposed transfer of the halftone pattern using the table emission time 12 μs, and the measurement emission time of 14 μs is obtained at the measured white-to-black ratio 55% in case of departing from the white-to-black ratio range equal to or more than 40% and less than 50%. In this case, the emission lag time is 2 μs, so that the regulation is made, for the actual printing use, to the corrected emission time 10 μs obtained by deducting the lag time 2 μs from the table emission time 12 μs.

FIG. **17** is a flowchart of the toner density measurement processing of the present invention which is the processing of step **S4** of FIG. **16**. First in step **S1**, the transverse line pattern of FIG. **10A** or the slanted line pattern of FIG. **10B** is developed after the exposure through the "1on3off" repetition in the vertical scanning direction of the exposure LEDs so that the halftone pattern is transferred onto the belt surface. Then a check is made in step **S2** to see if the toner mark on the belt has reached the sensor position so as to monitor the movement to the sensor position, more specifically, the belt running time from the halftone pattern transfer up to the sensor position, to thereby detect the movement to the sensor position. When the mark on the belt reaches the sensor position, the procedure goes to step **S3** to start the sampling of the output signals from the photodiode provided in the sensor and the sampled data D(i) are stored in the memory **106**. The memory storage of the sampled data in step **S3** is iterated till the mark end in step **S4**. When the mark is ended, the number NH of data higher than the predetermined threshold value TH is derived in step **S5** from the sampled data D(i) stored in the memory. Then in step **S6** the number NL of data lower than the threshold value TH is derived from the sampled data. Then in step **S7** the white-to-black ratio WBR is figured out from

$$WBR=\{NL/(NH+NL)\}\times100[\%]$$

Finally in step **S8**, reference is made to the density control parameter table **104** of FIG. **10** for the conversion into the emission time as the density control parameter, to terminate the series of measurement processes allowing the procedure to return to the main routine of FIG. **16**.

According to the present invention, as set forth hereinabove, the toner density is measured from the line width substantially proportional to the amount of toner adhesion of the transverse line pattern or the slanted line pattern transferred in the form of the halftone pattern, whereby it is possible to obtain the toner density through secure determination of the line width from the sensor read signal with possible attenuated quantity-of-light for not only the YMC color toners but also for K black toner without relying on the toner reflectance as in the conventional toner density measurement based on the reception signal of a reflected light by the toner diffuse reflection or regular reflection. It is also possible to measure the K black toner and the Y, M and C color toners by the same sensor, the same circuit and the same algorithm, with the high resistance to the analog noises and acquisition of stably high measurement accuracy by virtue of the detection of the line width. Furthermore, the sensors for the toner density detection of the present invention can be of the same sensor structure as that of the sensor for correcting the toner positional offset which similarly effects its work through the toner mark transfer on the belt surface, whereby a single sensor can be used for both the toner positional offset and the toner density measurement to thereby reduce the sensor configuration and costs.

Although the above embodiments have been directed to the printing apparatus using the Y, M, C and K color toners by way of example, it would be applicable intactly to any appropriate apparatuses as long as they transfer a plural kinds of color toners onto the sheets by use of electrostatic recording units which are arranged in tandem. The present invention is not to be limited to the above embodiments but it could variously be modified without departing from its object and spirit. The present invention is not to be restricted by the numerical values indicated in the above embodiments.

What is claimed is:

1. A printing apparatus comprising:

a belt unit which conveys record sheets on a belt at a constant speed, said record sheets being electrostatically adhered to a surface of said belt;

a plurality of electrostatic recording units arranged in a direction of conveyance of said record sheets, said electrostatic recording units forming a latent image corresponding to image data through an optical scanning on a photosensitive drum in rotation by an exposure device, said electrostatic recording units developing said latent image with a toner component of different color, to thereafter transfer said developed image onto said record sheets lying on the surface of said belt;

a toner transfer unit which transfers a halftone pattern onto the surface of said belt by use of said plurality of electrostatic recording units;

a sensor unit which optically reads said halftone pattern transferred onto the surface of said belt; and

a toner density measurement unit which measures a toner density on the basis of a ratio of a reflected light from a toner bearing portion to a reflected light from a toner free portion in a read signal of said halftone pattern from said sensor unit.

2. A printing apparatus according to claim **1**, wherein

said toner transfer unit transfers one of a transverse line pattern and a slanted line pattern on the surface of said belt, a line width of said one of transverse line pattern and said slanted line pattern varying in proportion to the toner density.

3. A printing apparatus according to claim **2**, wherein

said toner density measurement unit samples at a predetermined cycle a sensor output signal of said one of transverse line pattern and said slanted line pattern transferred onto the surface of said belt, said toner density measurement unit determines a white-to-black ratio using a formula NL/(NL+NH) wherein NH represents a sampled data having a higher value than a predetermined threshold value and NL represents a sampled data having a lower value than said predetermined threshold value.

4. A printing apparatus according to claim **1**, wherein

said toner density measurement unit refers to a predetermined table information defining a relationship between a white-to-black ratio and a density control parameter, to determine whether said density control parameter corresponds to an amount of adhesion of toner.

5. A printing apparatus according to claim **4**, wherein

said density control parameter is an emission time when an amount of current flowing per dot of said exposure device is constant or an amount of current when the emission time per dot of said exposure device is constant.

6. A printing apparatus according to claim **1**, wherein

said sensor unit includes a condenser lens through which a light from a laser diode impinges on the belt surface in the form of a spot light of the order of several tens of microns, said sensor unit, when no toner components adhered thereon the surface, provides a signal of a reflected light, said reflected light being received by a light reception element arranged in a direction of a predetermined output angle, said sensor unit, when toner components adhered thereon the surface, provides a signal of a light attenuated due to scattering of said spot light, said attenuated light being received by said light reception element.

7. A printing apparatus according to claim **1**, wherein

said sensor unit has an incident angle $\theta 1$ from a laser diode relative to the belt surface and an output angle $\theta 2$ from the belt surface relative to a light receiving element, said incident angle $\theta 1$ and said output angle $\theta 2$ being set to a range between 60 and 80 degrees, preferably in a vicinity of 70 degrees.

8. A toner density measuring method for a printing apparatus having a belt unit which conveys record sheets on a belt at a constant speed, said record sheets being electrostatically adhered to a surface of said belt, and having a plurality of electrostatic recording units arranged in a direction of conveyance of said record sheets, said electrostatic recording units forming a latent image corresponding to image data through an optical scanning on a photosensitive drum in rotation by an exposure device, said electrostatic recording units developing said latent image with a toner component of different colors, to thereafter transfer said developed image onto said record sheets lying on the surface of said belt, said method comprising a plurality of steps of:

transferring a halftone pattern onto the surface of said belt by use of said plurality of electrostatic recording units;

optically reading said halftone pattern transferred onto the surface of said belt, by use of a sensor unit; and

measuring a toner density on the basis of a ratio of a reflected light from a toner bearing portion to a reflected light from a toner free portion in a read signal of said halftone pattern.

9. A toner density measuring method according to claim **8**, further comprising a step of:

transferring one of a transverse line pattern and a slanted line pattern on the surface of said belt, a line width of said one of transverse line pattern and said slanted line pattern varying in proportion to the toner density.

10. A toner density measuring method according to claim **9**, further comprising a plurality of steps of:

sampling at a predetermined cycle a sensor output signal of said one of transverse line pattern and said slanted line pattern transferred onto the surface of said belt; and

figuring out a white-to-black ratio by using a formula NL/(NL+NH), wherein NH represents a sampled data having a higher value than a predetermined threshold value and NL represents a sampled data having a lower value than said predetermined threshold value.

11. A toner density measuring method according to claim **10**, further comprising a step of:

referring to a predetermined table information defining a relationship between said white-to-black ratio and a density control parameter, to determine said density control parameter corresponding to the toner density.

12. A toner density measuring method according to claim **11**, wherein

said density control parameter is an emission time when an amount of current flowing per dot of said exposure device is constant or an amount of current when an emission time per dot of said exposure device is constant.

13. A toner density measuring method according to claim **8**, wherein

said sensor unit includes a condenser lens through which a light from a laser diode impinges on the surface of said belt in a form of a spot light of an order of several tens of microns, said sensor unit, when no toner components adhered thereon the surface, provides a signal of a reflected light of said spot light, said reflected light being received by a light reception element arranged in a direction of a predetermined output angle, said sensor unit, when toner components adhered thereon the surface, provide a signal of a light attenuated due to scattering by said spot light, said attenuated light being received by said light reception element.

14. A toner density measuring method according to claim **8**, wherein

said sensor unit has an incident angle θ**1** from a laser diode relative to the surface of said belt and an output angle θ**2** from the surface of said belt relative to said light receiving element, said incident angle θ**1** and said output angle θ**2** being set to a range between 60 and 80 degrees, preferably in a vicinity of 70 degrees.

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